PERIODICAL ROOM
GENERAL LIBRARY
UNIV. OF MICH.

OCT 25 1929

THE NOVEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

BIOLOGICAL STATIONS OF JAPAN. PROFESSOR M. F. GUYER 385

THE GERMAN CARP, AN INVITED IMMIGRANT. PROFESSOR W. M. SMALLWOOD and MARY L. SMALLWOOD 394

NOTABLE PROGRESS IN SURVEYING INSTRUMENTS. DR. WILLIAM BOWIE 402

MATHEMATICAL DESERTS AND SOME OF THEIR OASES. PROFESSOR G. A. MILLER 407

THE CONFLICT OF THE PSYCHOLOGIES. PROFESSOR JOSEPH JASTROW 411

THE PREEMINENCE OF PRIMARY EXPERIENCE. PROFESSOR J. HOWARD STOUTEMYER 417

SCIENCE AND IMAGINATION. PROFESSOR WARREN WEAVER 425

HOW THE LAUGHING GULL GETS ITS DINNER. DR. E. W. GUDGER 435

THE USEFULNESS OF THE USELESS. DR. CHAS. N. GOULD 440

SIR HUMPHRY DAVY. PROFESSOR BENJAMIN HARROW 447

EXTENT OF PERSONAL VOCABULARIES AND CULTURAL CONTROL. PROFESSOR J. M. GILLETTE 451

TROPICAL MEDICINE. PROFESSOR ALFRED C. REED 458

THE SIGNIFICANCE OF BOUNDARY CONDITIONS IN PHYSICS. PROFESSOR R. B. LINDSAY 465

THE PROGRESS OF SCIENCE:

The Presentation of Down House to the British Nation; Dr. Britton and the New York Botanical Garden; Dedication of the Chemistry Building at Princeton University 472

THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

NEW BOOKS OF SCIENTIFIC INTEREST

The Adolescent; His Conflicts and Escapes. SIDNEY I. SCHWAB and BORDEN S. VEEDER. 365 pp. $3.00. D. Appleton and Company.

Two eminent physicians, both at the Washington University Medical School, have collaborated in presenting in this comprehensive survey the results of many years of clinical experience in dealing with the problems of the adolescent period.

ABC of Television, or Seeing by Radio. RAYMOND FRANCIS YATES. viii + 210 pp. Illustrated. $3.00. The Norman W. Henley Publishing Company.

The "ABC of Television" aims to be an easily understood and practical book containing descriptions of television systems and also detailed information concerning many television experiments that may be conducted with modest equipment.

General Chemistry. A Text-book for College Students. JOSEPH A. BABOR. x + 586 pp. 167 figures. $3.75. Thomas Y. Crowell Company.

This new text-book for students who have had a high-school course in chemistry presents a thoroughly modern point of view; it emphasizes principles rather than descriptive details and it is built closely upon the atomic structures.

Laboratory Manual in General College Chemistry. JOSEPH A. BABOR and ALEXANDER LEHRMAN. viii + 376 pp; about half of these are blank pages. $2.00. Thomas Y. Crowell Company.

The authors have endeavored to employ only the simplest apparatus and to avoid the use of expensive chemicals. The manual stresses quantitative relations and offers many experiments to illustrate this phase of chemistry.

Structure and Surface. A Book of Field Geology. C. BARRINGTON BROWN and F. DEBENHAM. vii + 168 pp. 105 figures. $4.20. Longmans, Green and Company.

A non-technical book, well suited for those who have had no special training in geology. The simpler geological structures are illustrated by a general and idealized block diagram and also a diagram of tracts of the earth's surface.

The Universe around Us. JAMES JEANS. x + 341 pp. 24 plates. $4.50. The Macmillan Company.

Sir James Jeans, whose professional books are so widely known, has here written a book for the layman. In a non-technical style, he roves through the mysteries of modern physics and astronomy, opening up new vistas for the imagination.

Applied Geophysics in the Search for Minerals. A. S. EVE and D. A. KEYS. x + 253 pp. 92 figures. $4.50. The Macmillan Company.

The authors' aim is to describe the practical and theoretical sides of the many scientific methods of mining exploration now available. The book is based on actual experience in the field.

Principles of Animal Biology. A. FRANKLIN SHULL. With the collaboration of George R. Larue and Alexander G. Ruthven. Third edition. xiv + 405 pp. 266 figures. $3.50. McGraw-Hill Book Company.

A presentation of basic principles and broad generalizations for elementary students. The principal changes in this edition are in that section of the book dealing with morphology and physiology of higher types.

Introduction to Quantitative Analysis. EDWARD G. MAHIN. xii + 227 pp. 32 figures. $2.25. McGraw-Hill Book Company.

A text-book in chemistry prepared especially for technical and engineering schools. More laboratory work is described than can be completed in an ordinary college course.

Science and the Unseen World. ARTHUR STANLEY EDDINGTON. 91 pp. $1.25. The Macmillan Company.

The contents of this little book were presented as a lecture by the author in London. The essay is a philosophical discussion of the relations of science and religion and the part they play in the life of man.

Microbiology. BENJAMIN FRANKLIN LUTMAN. x + 495 pp. 211 figures. $4.00. McGraw-Hill Book Company.

A treatise on molds, yeast and bacteria and their destruction of organic compounds. The general scheme of presentation has been to describe types which are common and have biological and practical importance.

Field Book of the Skies. WILLIAM TYLER OLCOTT and EDMUND W. PUTNAM. xv + 534 pp. Illustrated. $3.50. G. P. Putnam's Sons.

A clear and concise presentation of the main facts of modern astronomy, a brief story of the mythology of the constellations and a practical field book for the observer of the stars.

The Earth. Its Origin, History and Physical Constitution. HAROLD JEFFREYS. Second edition. xi + 346 pp. $6.50. The Macmillan Company.

This book deals with the major problems of the physical constitution of the earth and the phenomena of isostasy and mountain-building. Its aim is to discuss the theories of the main problems of geophysics and their interrelations.

The Idea of Value. JOHN LAIRD. xx + 384 pp. $5.50. The Macmillan Company.

This book, by the regius professor of moral philosophy at Aberdeen, is an attempt to examine the conceptions of value, particularly esthetic, economic and moral values, with special reference to the opinion of philosophers.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1929

BIOLOGICAL STATIONS OF JAPAN

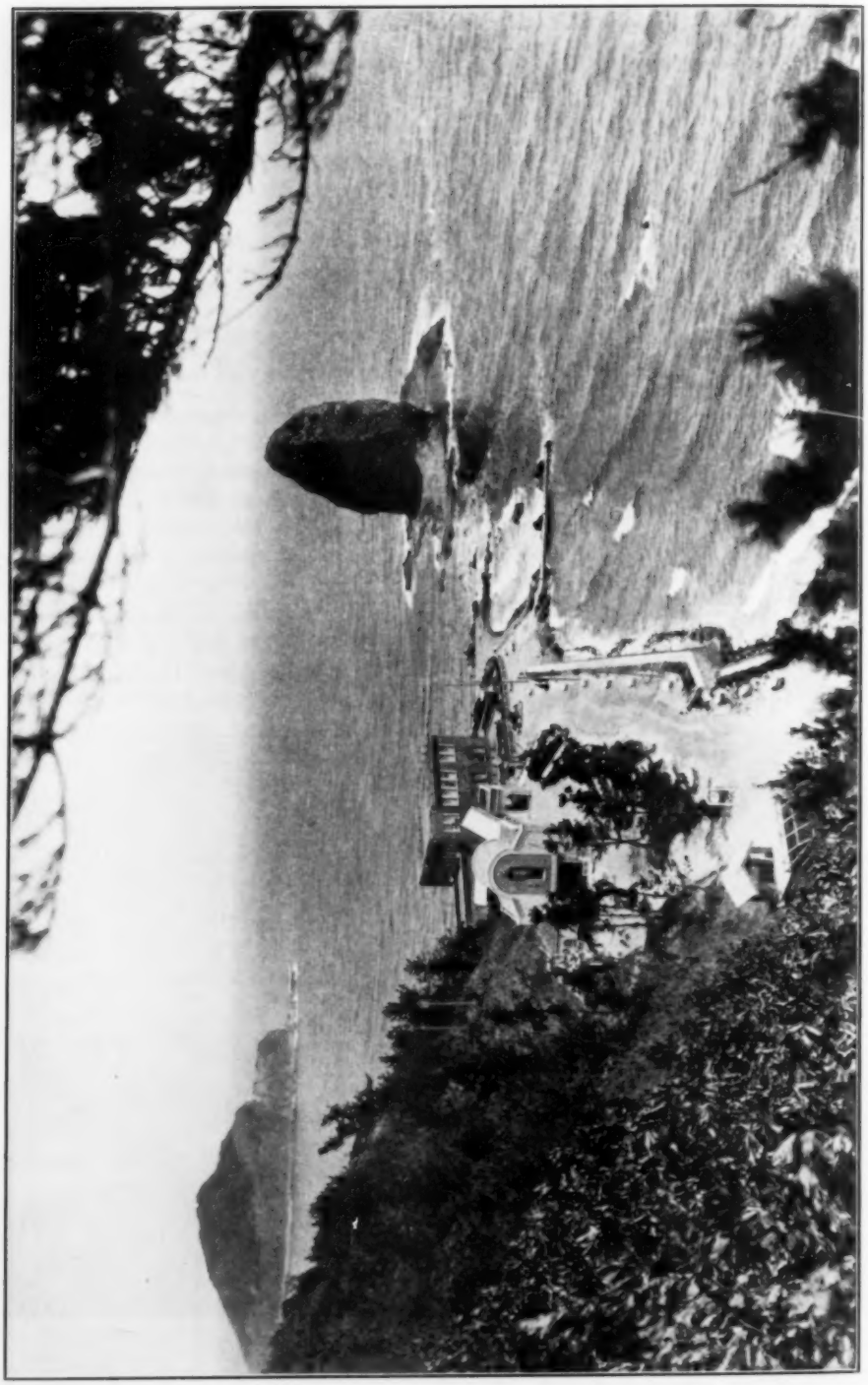
By Professor M. F. GUYER

DEPARTMENT OF ZOOLOGY, UNIVERSITY OF WISCONSIN

THE MARINE BIOLOGICAL STATION AT ASAMUSHI

RARELY indeed can the zoologist command a modern, well-equipped laboratory and veritable fairy-land of natural enchantment all in one setting, but exactly this combination awaits the scientist who chooses to visit the Marine Biological Station at Asamushi. Situated on the northeastern coast of the main island of Japan, seventeen hours' rail journey from Tokyo and eight from Sendai, this up-to-date attractive establishment, which compares favorably in equipment with any marine laboratory in the world, offers its hospitality to native and foreigner alike. To speak of the low cliffs, the rocky beaches, the wild, indented shore-line, the mountainous hills which spring abruptly from the sea, the beckoning coves and channels, is but to catalogue the material realities of the place, whereas it is, in fact, an indescribable ethereal quality which lays

GENERAL VIEW OF ASAMUSHI,
A SUMMER RESORT WITH HOT SPRINGS AND EXCELLENT SEA-BATHING, ABOUT TWO MILES DISTANCE FROM THE STATION.



VIEW OF THE AQUARIUM BUILDING

(WITH CURVED ROOF) AND THE MAIN LABORATORY BUILDING BEYOND AS SEEN FROM A NEARBY HILL.

DORMITORY AND REFECTORY WITH OFFICIAL RESIDENCES BEYOND.

hold of the senses when one visits this land of pastel hues, mysterious hazes and cameo-cut perfections.

Although located in a part of Japan where little English is spoken, American students need fear no serious linguistic inconveniences, for the hospitable director is none other than Professor Shinkishi Hatai, so closely identified with American zoology through over twenty-five years of sojourn in the Universities of Chicago and Cincinnati and the Wistar Institute, that we regard him as practically one of our own citizens. Speaking English himself and with four children reared in the schools of America it is needless to say that English is almost as current a language at the station as Japanese itself.

The station was founded in July, 1924, and is an extension of the Institute of Biology, Tohoku Imperial University, of Sendai, Japan. Although intended primarily for the students and faculty of its own university, investigators are welcomed at any time. The dormitory and staff residences are open the year round, although summer and autumn are the seasons of greatest activity. In the summer of 1928 the staff and employees numbered fourteen, with Professor Hatai as director, Assistant Professor Seiji Kokubo, administrator, and three assistants—Shunichi Takasuki, Yoshiro and Sadao Tanohe—serving as resident naturalists.

The chief structures consist of a commodious, well-equipped laboratory building, a large concrete aquarium building which houses a series of beautifully maintained aquaria and a museum, a combined dormitory and refectory which accommodates about fifty persons, and four official residences. A unique feature of the station is an under-sea laboratory designed for studies in experimental evolution, physiology and ecology. This building is half submerged in the sea at the shore-line with the floor about six feet below sea-level. The aquaria in it are supplied by the ebb and flow of natural sea-water, with temperature, salinity and other conditions similar to those of the open sea, so

NEARER VIEW OF AQUARIUM BUILDING AND THE MAIN LABORATORY.

PLAN OF BUILDINGS AND GROUNDS

1. Laboratory. 2. Aquarium house. 3. Boarding house. 4, 5, 6, 7. Residences. 8. Boat house. 9. Breakwater. 10. Marine pool. 11. Pumping house. 12. Undersea laboratory. 13. Electric plant. 14. Aquarium. 15. Meteorological screen. 16. Gas generating plant. 17. Storage. 18. Reserve house for living fishes. 19. Toilet. 20. Monkey house. 21. Bird house. 22. Bird house. 23. Monkey house. 24. Salt-water tank. 25. Fresh-water tank. 26. Flag pole. 27. Pier. 28. Storage. 29. Well. 30. Fresh water well.

that experimental marine animals may live under practically normal conditions. Lighting can be controlled at will.

The main laboratory is a two-storied brick building with eight research rooms for the faculty, a large laboratory for general students, a physiological laboratory, a biochemical laboratory, a dark-room and sundry other rooms all furnished both with running sea and fresh water. This building also houses the library.

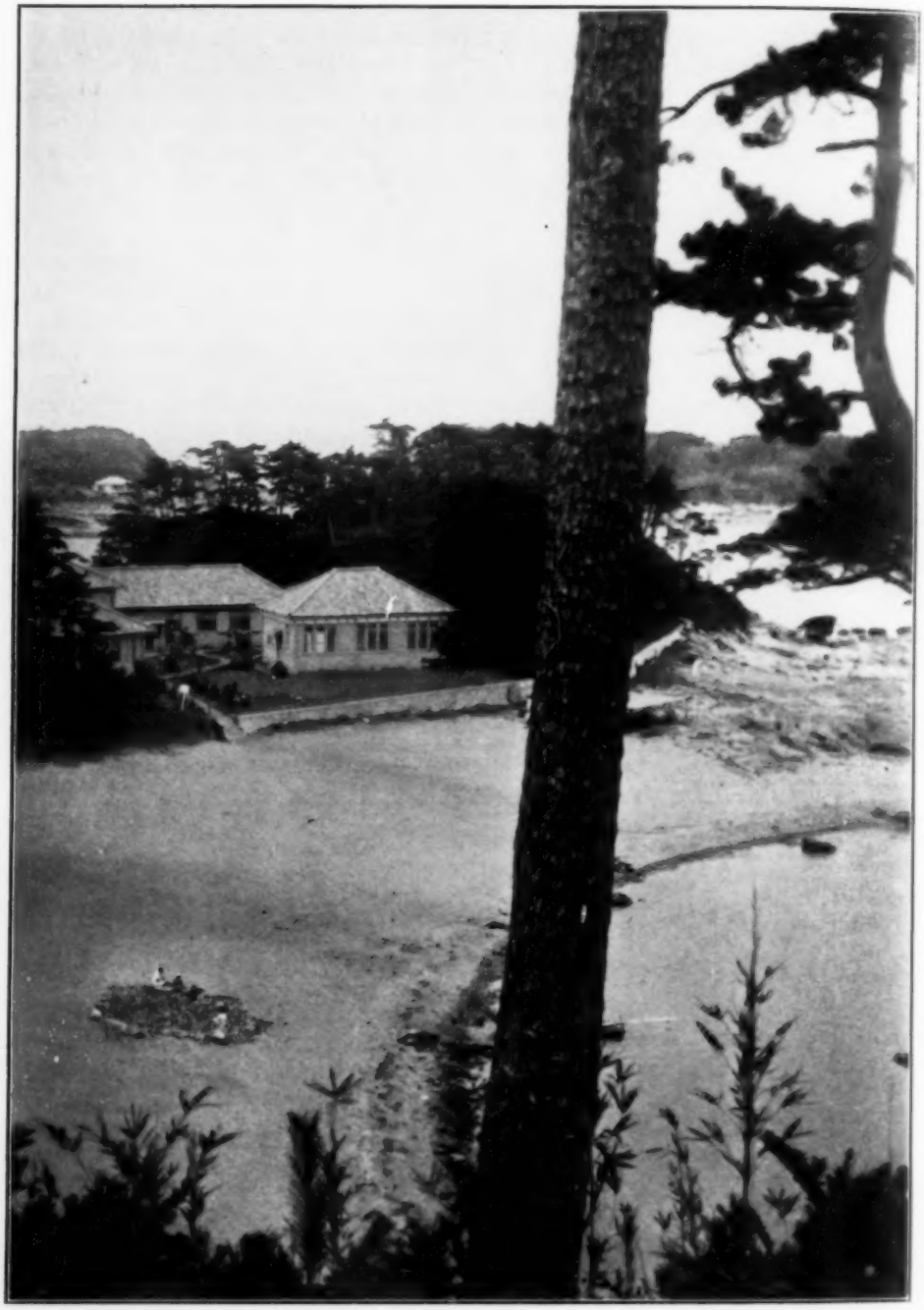
Two motor-boats are used in collecting and transporting various marine forms during all but the coldest part of the year. The exhibits in the aquarium building are discontinued for the winter in November of each year. Although the fauna and flora are less rich than those of southern Japan, an unlimited supply of the larger starfishes, ascidians, brachiopods, Pectens and Caudina is easily available and supplies the needs of students of experimental zoology and physiology.

The steady stream of publications which issues from this station abundantly testifies to the zealous activity of Director Hatai and his associates. The accompanying photographs give some idea of various features of this splendid, modern institution.

THE MISAKI MARINE BIOLOGICAL STATION

Less than three hours' rail journey from the busy life of Tokyo, amidst a romantic setting of both landscape and history, is situated the Misaki Marine Biological Station. It lies in about the same latitude as Los Angeles, on the southern extremity of a peninsula which separates the Bay of Tokyo from Sagami Sea. Just as the Marine Laboratory at Woods Hole in America prides itself on its early associations with Agassiz so this Japanese station is linked even more closely with the late Professor Mitsukuri, who was to zoological science in Japan much what Agassiz was in America. The Misaki laboratory, indeed, antedates that at Woods Hole by one year. It was originally erected in

THE MISAKI MARINE BIOLOGICAL STATION; DR. YATSU AT THE OARS.



A BIT OF THE SHORE AND THE RESEARCH LABORATORY
OF THE STATION, VIEWED FROM A NEARBY HILL.

SEASIDE CLUB FOR STUDENTS,
DINING-ROOM AND SOCIAL HALL.

1887 by the Japanese Department of Education, at the suggestion of Professor Mitsukuri. The three great guiding spirits of this laboratory who have been its successive directors—Mitsukuri, Iijima and Yatsu—are too well known to American zoologists to require comment.

Though fascinating ruins and legends claim the attention at every turn on the peninsula, and pine-covered hills with beautiful vistas of sea and mountain invite one to linger and dream, the outstanding attraction to the zoologist is the laboratory and what goes with it. No marine station in the world, not even the far-famed ones of the Mediterranean, can outvie that of Misaki in variety and richness of fauna and flora. Tide-pools, rocky shores, sandy, stony or rocky beaches, mud flats, projecting ledges, cliff caves, all combine to form a "happy hunting ground" for the zoological enthusiast. Also, in the winter months when strong west winds blow, an amazingly rich plankton is driven into the inlets from its usual home in the "Black Current." One then may find *Salpae*, *Porpitae*, various interesting Heteropods and Pteropods, compound Radiolarians, *Auriculariae*, and what not. Within half a mile of shore one may reach a depth of ten fathoms, and three or four miles out a depth of one hundred fathoms, beyond which deep-sea forms of wonderful variety and beauty dwell. Exquisite glass sponges, stalked crinoids, large sea-spiders, red brittle-stars, giant crabs which measure ten feet from claw to claw, orange-colored hydroids standing a foot high, unique octopi and gelatinous sea-cucumbers may be found. There, also, live luminous black sharks and archaic sharks with more than five gill-clefts.

With the appointment of Professor Yatsu, of Tokyo Imperial University, to the directorate, in addition to facilities

JAPANESE FISHING BOAT
SAILING FROM THE STATION.

for faunistic studies, the equipment has been expanded to provide for physiological and chemical work. Regular courses are given in marine zoology for biology teachers, in fisheries and in planktology and oceanography. It is to the investigator, however, that the laboratory holds out the greatest attraction.

The station proper consists of four buildings: (1) a library and herbarium of land and marine plants together with research rooms for investigators; (2) a general student laboratory; (3) an aquarium and motor room, and (4) a two-storied museum in which are two bedrooms for overseas investigators. In addition are the various homes of the staff.

One has only to climb Azalea Hill, a pine-clad elevation ornamented with wild azaleas, to get an "aeroplane" view of the whole surrounding region of romance and beauty. Directly across the bay, towering high above the sea, stands sacred Mount Fuji.

The following interesting account of the effect of the great earthquake of 1923 on the fauna and flora of the region is given in the words (written in 1926) of the present director of the station, Professor Naohide Yatsu:

> With the first and greatest shock the water rushed out of the inlets with tremendous rapidity. The sea then rose higher and higher—very much higher than at high tide—and the water receded for good. The land was thus raised nearly four feet above its former level. The elevated part can now be seen as a whitish zone with dead barnacles and oyster-shells. In passing, it may be mentioned that most of these dead barnacles (*Tetraclita porosa*) are now occupied by spiders. The drying up of the sand beaches and mud flats killed all the dwellers there, such as cake-urchins, bivalves and annelids. Most of the green algae, *Renicra*, a very common sponge encrusting the rock, disappeared, but in the past two years new colonies have established themselves, springing from those that survived. The red actinians (*Actinia equina*) are gone forever, but the *Onchidia* are coming back.
>
> That immense quantities of shore-sponges were killed by the earthquake can be seen from the sudden increase of monoaxon spicules in the beach sands.
>
> On the morning of the earthquake, fishermen out on the fishing ground found many dead deep-sea fish of the cod family (*Physiculus*)

floating on the surface of the sea. At this phenomenon they were frightened, thinking something unusual would happen, and so they at once hastened back to land. There they soon witnessed what the earthquake had done. Undoubtedly the fish were killed by the sudden rushing of water into a newly formed depression at the bottom of Sagami Sea.

One more thing worth mentioning is that cicadas had been very abundant every year before the earthquake, but in the two summers after the disaster the cicadas considerably decreased in number. This was, I think, due to the fact that the larvae were crushed in the earth during the earthquake.

Quite recently two places of unusual scientific interest have been discovered near the laboratory by A. Imamura, professor of seismology at Tokyo Imperial University, one on an almost vertical cliff just below Arai Heights and the other on a hillside close to the rice-fields at the head of Moroiso Creek. At the latter place he found four rows of holes in the rock, one above another with intervals varying from 1.5 to nearly 3 meters. The holes were once inhabited by date-shells (*Lithophaga nasuta*), a species closely allied to *L. dactyla*, the holes of which made the pillars of the so-called Temple of Serapis at Pozzuoli very famous. Professor Imamura can tell us from these holes the approximate year in which took place four sudden upheavals of land due to earthquakes comparable in magnitude to the one which occurred in 1923. The lowest row indicates the high-tide mark prior to the earthquake of 1703.

The accompanying photographs, supplied through the kindness of Dr. Oshima, speak for themselves regarding the comforts, beauty and attractions of the place. Nowhere in the world will the American zoologist meet greater courtesy and hospitality than at the hands of the friendly director, Professor Yatsu, who is already widely known and beloved of American zoologists.

VIEW OF ABURATSUBA BAY

WHERE THE STATION IS LOCATED. A FLOAT FOR OYSTER CULTURE IS SEEN IN THE DISTANCE, AND DR. OSHIMA AND STUDENTS IN THE BOAT.

THE GERMAN CARP, AN INVITED IMMIGRANT

By Professor W. M. SMALLWOOD and MARY L. SMALLWOOD

DEPARTMENT OF ZOOLOGY, SYRACUSE UNIVERSITY

THE immigrant has come to have an important place in our twentieth century thinking. Congressmen are besieged with propaganda in behalf of each of the various nationals, but less of popular thought is given to the many animal immigrants, although they frequently cause the greater economic problem.

Most of our attention as scientists has been given to the economic aspects of these entrants as they affect our agricultural products, while in contrast to this careful study the life of the immigrant animals in our fresh waters has been scarcely touched. One of the reasons why this interesting problem in adaptation in a nearly uniform environment has been neglected is due to the difficulties in the problem itself. This article aims to assemble some observations on the immigrant carp in the hope of throwing light upon the adaptations of this very old fish as it has adjusted itself to our American waters. The observations are of too preliminary a character to justify any far-reaching conclusions, but it is our thought that this summary may serve as a starting-point and that in a few years adequate interpretation can be made.

De Kay places the first introduction of carp into New York waters at 1831. These were reared in ponds and later placed in the Hudson River.

Another of the early references to the successful introduction of the carp into America is found in the *Transactions of the American Institute* for 1850, and reads as follows:[1]

Mr. Meigs.—We are pleased to see among us Captain Robinson, of Newburgh, who brought the carp from England several years ago—thus conferring a great benefit upon this country by adding a fish before that unknown in our waters.

Captain Robinson.—I brought the carp from France about seven years ago, put them in the Hudson River, and obtained protection for them from our legislature, which passed a law imposing a fine of $50 for destroying them.

There is evident pride in this report, and the fact that a fine for destroying carp had been authorized by the legislature indicated great expectations as to the quality of this foreign fish. Various other attempts were made to introduce the carp to American waters, and as soon as the U. S. Fish Commission was established, the commissioner of fisheries gave attention to the importation of carp from Europe. By 1877, shipments were made from Washington and the applications came in so rapidly that, in 1882, seven thousand requests for carp were received. The distribution of carp continued until 1896. From that time on this fish had become sufficiently adapted to our American waters to need no further fathering care from the Bureau of Fisheries; in fact, it took so kindly to the American environment that it developed and spread until it is to-day regarded as a menace in a large number of our fresh-water ponds and streams. By some strange coincidence the English sparrow was introduced in the same year, 1850, with the hope that it might feed upon some of our noxious insects. The story of the distribution of the English sparrow, which has only recently ceased to be a serious pest, is well known. Will the immigrant carp pass through a similar series of adjustments?

During the summer of 1927, the New York State Conservation Commission undertook an extensive study of the carp problem which was continued in 1928

[1] Leon J. Cole, 1905, "German Carp in the United States." Report of the U. S. Bureau of Fisheries, pp. 523–641. Illustrated.

and will no doubt be carried on for some time. The writers of this article were members of the scientific staff for the Oneida Lake Survey of the Carp Control Studies in 1927, and have drawn largely upon the data collected then and in 1928, as well as upon their own studies,[2] for facts stated here.

During the latter part of June, depending upon the temperature of the water, the carp seek the bays of Oneida Lake and deposit their eggs on the shore plants. The filamentous algae, *Chara*, and the small *Potamogetons* are covered with masses of eggs. During the summer of 1928, eggs were very abundant from June 26 to July 5, although the spawning period ranged from May 14 to July 7. We were able to hatch eggs in the pike-perch hatchery jars of the Constantia Hatchery, although eggs placed in the bass net cages in the shallow waters at the edge of the lake died within three days.

The carp eggs in the jars hatched in from five to seven days, although the usual time given is from twelve to fifteen days. The embryo begins to move within the egg envelope in two days. This rate of development is very rapid and the eggs of the same batch hatch into active swimming forms at variable periods of about twenty-four hours. The mortality of the eggs on the shore was very great as these were noted from day to day. The eggs which were not developing turned whitish.

[2] W. M. Smallwood and Parke H. Struthers, Conservation Commission, 1928, "Carp Control Studies in Oneida Lake."

—*New York State Carp Control Studios*

FIG. 1. WEIGHING, MEASURING AND TAKING A SCALE FROM AN ADULT CARP FOR AGE DETERMINATION.

—Illustration from New York State Conservation Commission

FIG. 2. HABITAT SKETCH OF YOUNG CARP IN THE ADVANCED FRY STAGE.

As soon as the young carp escape from the egg envelopes and become free swimmers, they are not found living in schools as is the case with the adult carp and many of the young game fishes. The young carp can be easily distinguished from the young of other fish since they are a replica of the adult in form and in arrangement of fins. The back is much lighter in color than that of the adult, being a light mouse gray. At the base of the tail there is a vertically placed black bar, while the abdomen has a distinct yellowish tinge. When young carp are caught in a dip net this yellowish color and the deep body distinguish them from the very similar young suckers.

The young carp take up a habitat that is quite characteristic, in water that is free from sediment, decaying vegetable matter or contamination from creeks. The temperature of the water in these protected regions runs about ten degrees warmer than that of deep lake water. The shores bordering these carp habitats consist of low land covered with a growth of meadow grass or bulrushes with here and there small bayous extending shoreward. Each of these setbacks is carpeted with tender grass, with *Elodea, Chara* or *Myriophyllum,* in which the young carp live. As the carp increase in size, they move lakeward into deeper water. By September first, the young carp are living in one or two feet of water close by scattered beds of *Potamogeton pectinatus* or hornwort.

Invariably little carp will hide rather than seek safety in flight if molested. It is this characteristic which makes them so difficult to find. When catching them with a hand-net, it is possible to work over a whole bed of *Chara* or *Elodea* without driving the fish away. Not until they reach a length of about 100 mm do they seem to appreciate the possibility of fleeing from an intruder.

Small carp are very sensitive to temperature changes and also to impurities in the water. To test these reactions, young carp were placed in aquaria

with young sunfish, bullheads and common perch. A sudden change of temperature invariably affected the carp first. Any pronounced change in the hydrogen ion concentration, due to the presence of decaying matter, was fatal to the carp, although not to the other young fishes living with them. In these lake habitats young carp were never found in the vicinity of green algae such as *Spirogyra* or *Cladophora*, decaying vegetable matter or quagmires.

The rapid rate of growth of young carp is remarkable. This is shown in the following table, which gives the dates the fish were caught and the ranges in size in Oneida Lake.

July	12	10 mm long
July	21	12 mm– 26 mm
July	27	14 mm– 30 mm
July	29	12 mm– 40 mm
Aug.	12	38 mm– 42 mm
Aug.	20	41 mm– 78 mm
Sept.	5	80 mm–112 mm
Sept.	7	72 mm–106 mm

The feeding habits of young carp are very interesting as they were observed on Oneida Lake during the carp control studies in 1927. The fish places the mouth against the base of a stalk of *Chara* and draws into the mouth the minute animals, such as cyclops and daphnia, which are feeding on the stalk. The fish moves slowly up the stem on one side, then turns and cleans off the other side as it moves down to the base again. After this, the fish moves to another plant to repeat the operation. At times they work out onto the leaves, but never come to the surface of the water. Sometimes two fishes are working on one plant, each apparently unconscious of the other's presence. At intervals, a fish remains motionless, except for the slowly waving fins, and then darts off to a new clump of *Chara*.

More detailed observations of the feeding habits of the little carp were obtained from fish living in aquaria. The bottom of the aquarium was covered with fine sand and clay rich in organic material. Within a few days the surface showed numerous small pits. These were made by the young carp which often take a position forming an angle of about 90° with the bottom, and with the tip of the snout in the sand. Next, a cloud of sand is seen passing out of the opercular opening. Sometimes this is all that happens and the fish proceeds to swim about in the aquarium; but at other times the fish takes a position horizontal to the bottom and works the jaws repeatedly as if chewing, the jaws opening and closing from twelve to eighteen times. They also suck up a mouthful of the debris from the bottom, eject this from the mouth, then dart forward and gobble up bits of desirable food. The young fish living in aquaria frequently resort to top feeding, working here and there with their mouths just below the surface of the water, sucking up bits of floating matter. This is probably an unusual type of feeding for young carp in their natural haunts, for the fish lives near the bottom. Observations made on the stomachs of little carp taken at different hours indicate that they have rapacious appetites which compel them to forage for food at all hours of the day.

Young carp are very active, strong swimmers, and their inquisitive natures keep them continually exploring the domain in which they live, but they are so much more timid than our common game fish that it is difficult to observe them accurately. Their tendency to live in dense growths of water plants and to bury themselves in the mud indicates that the young fish may be, to some extent, negatively phototropic, in which respect their behavior differs from that of the adults, which show no aversion to light. The instincts seem to be poorly developed in the young carp, for they show no indications of pugnacity or, on

—Photograph furnished by New York State Conservation Commission

FIG. 3. YOUNG STAGES OF CARP. THE TWO SMALLEST FROM ONEIDA LAKE, JULY 21, 1927; YOUNG LEATHER CARP FROM CASSADAGA CREEK, JULY 14, 1925; LARGEST SPECIMEN FROM ONEIDA LAKE, SEPT. 15, 1927.

the other hand, of a tendency to be gregarious. A characteristic occasional darting about aimlessly through the water might be attributed to play.

Yearling carp range in length from six to ten inches. Bean[3] reports a growth of twenty-three inches in eleven months, a rate of growth which our study does not support. The two-year-olds grow rapidly in weight and in length but with no steady rate. There is a wide range in the weight and length of carp taken in a lake habitat where there is an abundance of food. Our studies indicate a wide range in growth. Sixty-two individuals that were judged to be five years old by the lines of growth on the scales ranged in weight from four to eleven pounds and varied in length from sixteen to twenty-six inches.[4] This variation in length and weight in the five-year age which was common in the specimens studied indicates that there is little significance in the older tables such as those published by Goode. This conclusion is further emphasized when we compare the range of weight for fishes in Oneida Lake having the same length, as indicated in the table.

The heaviest fish taken during the carp control studies weighed thirty-four pounds; while fifty-pound fish are reported from the Oswego River, it has not been possible to locate the man who weighed them. Bean reports European carp weighing sixty-seven and even ninety pounds, but gives the date, 1853. There are various extraordinary sizes that have been reported, mostly for European carp, but for which no exact data are available. The age of carp is perplexing; Bean reports one that attained an age of thirty-five years, but does not indicate the source of his information. Baird and Suffield report ages of 375 and 300 years.[5] The oldest carp taken by the carp control workers in 1927 was only thirteen years, when computed by the scale lines of growth. Does

[3] T. H. Bean, "New York State Fishes." 1903.

[4] For details see table in "Carp Control Studies." 1928.

[5] S. F. Baird, "Death of An Aged Carp," *Am. Rec. Sci.*, p. 262. 1872.

R. R. Suffield, "Longevity of the Carp," *Nature*, 10: 147. 1874.

VARIATION IN RANGE OF WEIGHT OF FISH OF THE SAME LENGTH TAKEN IN THREE HAULS OF THE SEINE IN ONEIDA LAKE IN 1928

Number of Individuals	Length in Inches	Weight in Pounds
1	7.5	0.7
1	11.5	1.25
1	12	1.4
1	13	1.5
1	14	2
2	15	2, 6
3	16	4, 5, 6
4	17	8, 5, 6, 5
5	18	5, 3, 4, 4, 3
6	19	5, 4, 5, 5, 4, 5
6	20	6, 7, 5, 5, 5, 6
12	21	6, 7, 7, 7, 7, 7, 7, 7, 6, 6, 8, 5
5	22	8, 7, 8, 10, 8, 9
9	23	13, 8, 9.11, 9, 9, 8, 8
5	24	10, 9, 10, 8, 9
5	25	10, 12, 10, 8, 9
5	26	13, 12, 10, 12, 10
5	27	14, 16, 18, 12, 11
3	28	12, 14, 14
4	29	15, 15, 15, 20
2	30	20, 18
4	31	18, 20, 24, 20
3	32	21, 20, 23
2	33	20, 20
1	34	21.5
1	35	24.75
1	39	29
1	40	32

this mean that they have been in Oneida Lake but thirteen years? This can hardly be the explanation, for they were placed in the Hudson River in 1831 when the Erie Canal had been completed for six years. Carp in the Hudson River would have easy access to the Erie Canal which would permit them to enter the numerous streams, ponds and lakes from Albany to Buffalo. It seems safe to assume that carp have been in Oneida Lake for much more than thirteen years. Where are the older carp?

In the early spring the carp are found in swamps and submerged lowlands where they may become stranded. As the warm weather of April comes on they begin to migrate to the shores from the swamps and from the deep water of the lake, becoming abundant in the shallow bays where vegetation is profuse. Here spawning takes place in June and July. After spawning, very characteristic schools of these immigrants may be found for the rest of the season in the shallow bays having abundant growth of pond weeds, a muddy or sandy bottom and a nearness to deep water. Because of their presence in such bays, they can be very conveniently baited with bread and corn, and consequently more easily seined. Until recently, carp have not been seined extensively in this country, since only certain groups of people have appreciated their value as a source of food.

The every-day diet of these immigrants may be summarized as "mites, entomostracans, oligochaetes, amphipods, snails, protozoans, silt, debris," according to one writer; and, according to another, as "principally vegetable matter, also insect larvae, crustaceans, mollusks and other aquatic animals," or they are "omnivorous and chiefly vegetarian in their diet." In the two years' work of the carp control studies on Oneida Lake and its tributaries, the food was found to be chiefly animal.

Carp are found inhabiting lakes, ponds, streams and canals. Such habitats vary in currents, amount of suspended matter, temperature and vegetative growth. In the large lakes the environment is practically stable, while in the shallow streams or the canal, temperature changes are more rapid and there is an extensive plant growth and even a large degree of pollution.

The question naturally arises as to how the carp has become adapted to such widely different habitats and able to flourish in all of them. Though it is to be noted that adult carp live in communities of their own nationality and that bass and pike move off the feeding grounds when a school arrives, there is more or less competition with the more

—Photograph furnished by New York State Conservation Commission

FIG. 4. A BOAT LOAD OF CARP—PART OF A CATCH WEIGHING ONE AND A HALF TONS.

highly specialized fishes. Like some of our human immigrants, the carp have come from crowded conditions in other countries where they were accustomed to live on inferior food. These same habits are retained in our spacious waters where they survive and reproduce under a more varied environmental condition than any single species of our native fish.

One phase of this adaptation may be in the food habits. Is there any other fish with such a cosmopolitan, yet plebeian, appetite? It would seem that in this respect our hardy immigrant has a distinct advantage over other fish which may be due in part to the peculiarity of its intestinal tract. In the adult there is a large intestine, but no stomach, and a combined liver and pancreas. The significance of these structural peculiarities is not fully understood as yet and is one of the problems that we are investigating.

During the summer of 1927, nearly fifty tons of carp were taken from Oneida Lake in the carp control studies. This would represent about nine thousand carp, ranging in age from three to thirteen years. In this large number there were no evidences of disease, and practically no abnormalities. A great many specimens exhibited from one to one half dozen lamprey scars, but in all our study of the shores of Oneida Lake, which has a shore-line of about sixty-five miles, we failed to find any numbers of dead carp. The observations extended from the middle of June until the middle of September. Similar observations in the summer of 1928 covered not only the lake, but all the Erie Canal from Utica, Lock 20, west to Lock 25, the Oswego Canal, Onondaga and Cross Lakes. This territory, covered by Professor Struthers,[6] represents three hun-

[6] Parke H. Struthers, "Carp Control Studies in the Erie Canal." New York State Conservation Commission Report for 1929. In press.

dred miles of actual shore-line. It was surveyed twice during the summer. This absence of disease in the lakes and streams and Erie Canal is duplicated by the observations of Professor R. V. Bangham, for Ohio, Professor A. C. Pearse, formerly of the University of Wisconsin, and Dr. George Hunter III for the Illinois region.

It is also to be noted that we found the carp to be remarkably free from parasites. The three men just noted report a similar freedom from parasites in the regions which they have studied. Ward, in 1912,[7] and Essex and Hunter, in 1926,[8] agree that the carp is relatively free from parasites. The only parasites of any frequency at all are forms that belong to Acanthocephala (hook-headed worms). These observations cover the Mississippi River basin. During the summer of 1928, Dr. Hunter observed carp in Lake Erie and its tributary waters and found only one parasitized carp. Professor Struthers found in Owasco Lake, during the month of October, that about one thousand carp had died very suddenly. He was not notified until the carp had been dead for some time, so that it was impossible to determine the cause. It was probably an epidemic. A similar condition was recently noted in Cayuga Lake. This general absence of parasites seems to be another illustration of an animal having left in Europe the intermediate hosts so necessary to the completion of the life-cycles of the parasites.

The most extensive account of disease of carp in American waters is by Dr. Thompson,[9] who believes that he has a definite instance of rickets and that the disease is evident from the fingerling stage throughout life. This malformation is closely associated with the presence of an increase of the sewage load of the Illinois River in the years 1916–18. The carp living in the greatly polluted water showed a retardation of growth. The carp control students have made similar observations on the effect of polluted waters. Young carp taken from the outlet of Onondaga Lake are only six inches long at the end of the first year. This is a marked retardation of growth as compared with those taken in non-polluted waters, where their length is about nine inches and the body much heavier.

It is interesting to compare the conditions of the carp in our American waters with those found in European and Chinese waters. Dr. J. T. Nichols, who has made an extensive study of the Chinese carp, has told the writers in a personal conference that the Chinese carp were subject to a large number of diseases and parasites. A similar condition is evident in the European carp.[10] How long will it be before this primitive bony fish repeats in our American waters its European and Asiatic history?

[7] H. B. Ward, "The Distribution and Frequency of Animal Parasites and Parasitic Diseases in North American Fresh-Water Fishes," *Trans. Am. Fish Soc.*, 41: 207. 1912.

[8] H. E. Essex and G. W. Hunter III, "A Biological Study of Fish Parasites from the Central States," *Trans. Ill. State Academy Sci.*, Vol. 19. 1926.

[9] D. H. Thompson, "The 'Knothead' Carp of the Illinois River," *Nat. Hist. Survey Ill.*, 17: 285. 1928.

[10] B. Hofer, "Handbuch der Fischkrankheiten." München, 1904.

M. Plehn, "Praktikum der Fischkrankheiten," in H. Dennell and H. N. Maier, "Das Handbuch der Binnenfischerei Mitteleuropas." Stuttgart, 1924. Bd. I, pp. 301–470.

NOTABLE PROGRESS IN SURVEYING INSTRUMENTS

By Dr. WILLIAM BOWIE

CHIEF, DIVISION OF GEODESY, U. S. COAST AND GEODETIC SURVEY

A SHORT time ago my attention was called to a very interesting book, entitled "Geodeasia: or, the Art of Surveying and Measuring of Land Made Easie" by John Love, printed in London in 1688. The author, in the first sentence of his "Preface to the Reader" asks, "What would be more ridiculous, than for me to go about to Praise an Art that all Mankind know they can not live Peaceably without?"

He then shows how surveying originated in Egypt where it was necessary to recover boundary marks of private property after overflows of the Nile which covered with mud the indications of the divisions of private property. From Egypt the art of surveying was taken into Greece and, no doubt, from that country was carried all around the Mediterranean region. The last part of Love's preface is of particular interest and significance as it is, in a sense, the inspiration of this paper. The author of the book says:

> I have taken example from Mr. *Holwell* to make the Table of *Sines* and *Tangents*, but to every Fifth Minute, that being nigh enough in all sense and reason for the Surveyor's Use; for there is no Man, with the best instrument that was every yet made, can take an Angle in the Field nigher, if so nigh, as to Five Minutes.

It seems incredible that the surveying art had not progressed beyond the ability of an engineer to measure an angle in the field with an accuracy greater than five minutes less than 250 years ago. To-day we have direction theodolites, read by micrometer microscopes to single seconds, which give closing errors of triangles in first-order triangulation averaging about 1″. The probable error of a direction resulting from the adjustment of an arc of triangulation of first-order is seldom greater than 0″.5.

The development of surveying instruments has really been due to the astronomers. They desired to make observations on the sun, moon, planets and their satellites, and on the stars, and, in order that the work might be done with satisfactory accuracy, they paid much attention to the development of the telescope.

In an article on the telescope by H. Dennis Taylor in the Encyclopaedia Britannica is the following statement:

> But it is quite certain that previous to 1600 the telescope was unknown, except possibly to individuals who failed to see its practical importance, and who confined its use to "curious practices" or to demonstrations or "natural magic." The practical discovery of the instrument was certainly made in Holland about 1608, but the credit of the original invention has been claimed on behalf of three individuals, Hans Lippershey and Zacharias Jansen, spectacle-makers in Middelburg, and James Metius of Alkmaar (brother of Adrian Metius the mathematician).

It is undoubtedly true that the use of the telescope by Galileo brought it into general use in astronomy. While he was not the inventor of the telescope, he must be given much credit for making its use popular.

Prior to the use of the telescope, surveying instruments had pointers or sights on them somewhat like the sights used on firearms. These, necessarily, were coarse and made it impossible to secure angle measurements of a high degree of accuracy. The telescope could not be used in making accurate observations, in either astronomy or surveying, until cross wires or lines etched on glass

were used in the common focus of the eyepiece and the objective. Various attempts were made to improve the telescope in order to measure diameters of small objects seen in the telescope. In an article in the Encyclopaedia Britannica, under the subject micrometer, Sir David Gill states that

> It became, in fact, essential to invent a "micrometer" for measuring the small angles which were thus for the first time rendered sensible. There is now no doubt that William Gascoigne, a young gentleman of Yorkshire, was the first inventor of the micrometer. William Crabtree, a friend of his, taking a journey to Yorkshire in 1639 to see Gascoigne, writes thus to his friend Jeremiah Horrocks. "The first thing Mr. Gascoigne showed me was a large telescope amplified and adorned with inventions of his own, whereby he can take the diameters of the sun and moon, or any small angle in the heavens or upon the earth, most exactly through the glass, to a second."

This letter, apparently, was the first written account of the micrometer, but there must have been rather rapid development shortly after this. In the same article is the statement:

> The Marquis Malvasia in his "Ephemerides" (Bologna, 1662) described a micrometer of his own invention. At the focus of his telescope he placed fine silver wires at right angles to each other which, by their intersection, formed a network of small squares.

The date 1662 is only twenty-six years before the publication of Love's book "Geodaesia." Apparently the telescope with cross wires had not been applied to the surveying instruments in England when Love's book was published. It would seem, though, that the telescope was employed in surveying work not many years later by J. and D. Cassini between 1683 and 1716 in measuring, by triangulation, a meridional arc of 8° 35′ extending north and south through Paris. It is evident that a telescope with cross wires was used by the Cassinis, for, otherwise, it would have been impracticable for them to execute triangulation of the degree of accuracy which was obtained on the Paris arc.

Early in the seventeenth century Willebrord Snell (occasionally called Snellius) made a great advance over the methods used by his predecessors by introducing trigonometrical methods in the measurement of distances across country. He was really the originator of triangulation, which is now the universally employed method in surveying and mapping large areas. He published a book in Leyden describing his work in 1617.

In observing the angles of the triangles of his arc he used a quadrant of a circle of about two feet in radius. This was graduated to two minutes and readings were estimated to single minutes.

In 1669 Picard began his arc measurement, which was one of the most famous in the history of measurements, to determine the length of a degree of latitude. His work was done more accurately than previous measurements, both because he used a longer base line and because, judging from the best evidence available, he seems to have been the first geodesist who used spider-wires in the telescope attached to his quadrant. His quadrant had a radius of thirty-eight inches and was graduated to single minutes. The quadrant had two telescopes, one fixed and the other movable.

In measuring the angles with the quadrant, it appears that the plane of the quadrant was placed in the plane of the observer and of the two objects to be observed on. This resulted in the determination of the inclined angle. Butterfield in his book entitled "The Figure of the Earth from Arc Measurements" makes the statement: "Picard's measurement as a whole was a step far in advance and may be said to be the starting-point for accurate determinations."

During the latter part of the seventeenth century the Cassini brothers began the extension northward of Picard's triangulation. The work was inter-

rupted but taken up again early in the eighteenth century. The triangulation was extended southward to Spain. Base lines were measured for the control of the lengths of the triangle sides. On their work they used a quadrant of thirty-nine inches radius. This was graduated to minutes and observations were made with two telescopes, one fixed and the other movable.

In determining the latitudes of the stations whose distances apart were measured by the triangulation, an instrument was used which had an arc of a circle ten feet in radius. This arc was twenty-six degrees in extent and was graduated to degrees and minutes.

The next important development in triangulation came with the measurement of the arcs of meridians in Lapland and Peru. The work on these arcs began about 1735. It would seem that at this time an improvement was made in the triangulation method by measuring the differences in elevation of the various triangulation stations which made it possible to compute corrections to the observed angles to reduce them to the horizontal plane.

These attempts to determine the lengths of degrees of latitude by triangulation methods had really no bearing on surveying and mapping at the time that they were made. The work was for scientific purposes only, but the knowledge gained in the attempts to measure long distances across the earth's surface was later used in surveying and mapping. The modern map and chart maker is, therefore, deeply indebted to these great pioneers in earth sciences who attempted to determine the length of a degree of latitude at different places and from that to derive the dimensions of the earth.

From what has been said above it can readily be realized that the instruments used in surveying property boundary lines at the time that Love wrote his book in 1686 were very crude affairs. Probably the compass with pointers similar to the Jacob's staff of a generation ago was the most accurate of the instruments employed.

The biggest step forward which was made in surveying methods was the designing and construction of a theodolite by Ramsden about 1787 while he was engaged on the English end of an arc of triangulation which was to connect the observatories of Paris, France, and Greenwich, England. For the first time it was possible to measure horizontal angles, therefore spherical angles involved in a triangle were obtained and the spherical excess could be applied before making the trigonometrical computations. Ramsden's theodolite was first called a direction instrument. A few years later the French observers designed a repeating theodolite. It is rather noteworthy that the French have since been partial to the use of repeating instruments in their triangulation while the English have clung to the direction instrument.

The horizontal circle of the Ramsden instrument was three feet in diameter; it was graduated to ten minutes and the position of the telescope at any pointing was read by micrometer microscopes to single seconds. Very little improvement in the design of theodolites has been made since this wonderful instrument was designed by Ramsden and made under his direction. The fundamental principles involved in that instrument are practically the same as those in the instruments of to-day. Of course there have been improvements, the most noteworthy being the perfection of graduation of theodolite circles. It is said that the first dividing engine was made in 1740. Probably it was a crude affair as compared with the wonderful machines used to-day. While formerly it was considered necessary to have a very large horizontal circle on theodolites in

order to provide a fair degree of accuracy in the graduations, to-day on the highest order of triangulation, circles eight to ten inches in diameter are considered large enough. In fact, the graduations on circles of the Wild and the Zeiss theodolites are made on glass circles only five inches in diameter. Remarkable results are obtained with these instruments.

In the United States, triangulation was begun by Hassler, who was appointed in 1816 the first superintendent of the Coast Survey (the designation was changed to Coast and Geodetic Survey in 1878). In 1811 Hassler had been commissioned by President Jefferson to travel abroad in Europe to contract for the purchase and supervise the construction of surveying apparatus. While there he visited geographic and surveying organizations in order to become familiar with the best practices and instruments employed in surveying, mapping and charting. Hassler was a great man and far ahead of his time, for he initiated methods for charting the coast which were considered extravagant and uncalled for by most engineers of his time. He asserted that the coast charting should be based on triangulation and he even foresaw the time when the property values in this country would be so great as to justify the cost of extending triangulation over its vast interior.

Hassler brought back from Europe the most modern surveying and astronomical instruments and he employed them on the surveys of the coast which he initiated. It is rather remarkable that the triangulation done by Hassler beginning in 1816 is now, 110 years later, considered standard in accuracy. None of Hassler's triangulation has been discarded because of crudeness or inaccuracy.

With the development of theodolites for use in triangulation in connection with arc measures for the determination of the shape and size of the earth and for connecting astronomic observatories, instruments based on the principle of the theodolite were made also for surveying purposes. To-day the compass is used only in the crudest surveying. The transit, which is a simplified theodolite, is used in all surveying for property lines and for engineering operations.

From the very crude measurements in the triangulation by Snell in 1615, we have now come to triangulation of almost incredible accuracy. The angles of the first-order triangulation of the United States are measured with an accuracy which gives an average closing error of a triangle of only about 1″. The maximum allowable error in the closure of a first-order triangle is about 3″. The closing eror of a triangle is the difference between the sum of the three measured angles and 180° plus the spherical excess of the triangle. The smallness of these errors may be visualized if we consider that the two sides of an angle of one second diverge only one foot at a distance of forty miles from the apex of the angle.

The Coast and Geodetic Survey has executed thousands of miles of arcs of triangulation in the United States for the control of property boundaries, engineering operations and topographic maps. In the recent readjustment of the arcs in the western half of the country into a single network the average closing error of a loop of triangulation was about 1 part in 450,000 of the distance around the loop. There were only two loop closures out of sixteen which were greater than 1 part in 200,000, and the maximum closure was only 1 part in 162,000.

There has been great development in the accuracy of base measurements. In the early days the crudest methods were used, such as counting the turns of a wheel while going from one end of the

base to another. Then came wooden rods, and metal rods of various kinds. Later the surveyor's chain was devised and then came the steel tape, and finally the tape made of the alloy of nickel and iron called invar. The name invar is an abbreviation of the word invariable, used in connection with this alloy because the coefficient of expansion of the alloy is very small. In fact, the change in length of the invar used in the base tapes for a given change in temperature is less than one tenth of the corresponding change for a steel tape.

The most accurate triangulation that has ever been done, as far as the writer is aware, was that in the vicinity of Pasadena, California, executed for the purpose of determining the distance between Mount Wilson and San Antonio Peak, to be used by Professor A. A. Michelson for his determination of the velocity of light. A base line was measured in the valley to the south of the line joining those peaks. The line was more than twenty miles long and the uncertainty in the measured distance between its ends was only 0.14 inch or 1 part in 11,600,000 of the length of the base. This is the probable error of the field measurements of the length. The actual error may have been considerably larger than the accidental error, but, even so, the accuracy of the measurement was very great.

Triangulation was executed to connect the line between Mount Wilson and San Antonio Peak with this base. The greatest precautions were taken during the measurement of the angles, and the deflection of the vertical due to attraction of local mountain masses was determined for each station in order that the horizontal angles measured with the theodolites could be corrected for the tilting of the vertical axis of the instrument. The probable error of the derived distance between the two peaks was 1 part in 6,800,000. It is reasonably certain that the distance furnished Professor Michelson was correct within one part in a million.

This brief sketch indicates that tremendous strides have been made in surveying methods during the past 250 years and that the surveyors and the map and chart makers are deeply indebted to the astronomers, who showed them how to determine latitudes and longitudes on the earth's surface, and to those investigators who wished to know the size of the earth. We have here another striking example of the practical application of the methods used in pure scientific research and the employment of the results for the welfare for humanity.

In preparing this article, the writer has used freely the information contained in various articles in the Encyclopaedia Britannica, in a text-book on "Geodesy and Least Squares" by Charles L. Crandall, and in "The Figure of the Earth from Arc Measurements" by Arthur D. Butterfield. The reader is advised to consult these books if he is interested in following the subject of surveying methods in more detail than is here given.

MATHEMATICAL DESERTS AND SOME OF THEIR OASES

By Professor G. A. MILLER

UNIVERSITY OF ILLINOIS

It is a somewhat singular fact that the well-known Egyptian work of Ahmes, written about 1700 B. C., opens with a small desert since the operation of expressing rational fractions in terms of the sum of fractions having unity as a common numerator and distinct denominators has not proved to be of much importance, notwithstanding the fact that we find evidences of its use extending over a period of more than three thousand years. An oasis in this desert is due to the fact that this operation simplifies the notation of rational fractions since the only rational numbers which required consideration in this system are the positive integers and their reciprocals. While this work of Ahmes opens with a small desert it should not be inferred that its contents are entirely of this character. On the contrary, it exhibits the elements of the very fertile interplay of analysis and geometry as well as the elements of the fertile use of an operand symbol for the unknown.

The Great Sahara of mathematics is formed by the almost endless variety of the notations employed therein. A fertile oasis in this desert is due to the great value of a good notation and the discrimination involved in its selection. Even the numerical notations which have been used present a vast amount of material which is almost barren as regards fruitful ideas. In particular, the various notations leading up to our common numerals present little that is thought-inspiring since many of the changes involved therein seem to be due to chance and not to a well-planned general scheme. These notations, are, however, of much greater interest than those employed by many other peoples, such as the Babylonians and Chinese.

A mathematical desert of considerable size has been formed by the philosophical speculations relating to the properties of numbers. This type of speculation has been especially associated with the name of Pythagoras. According to Aristotle the Pythagoreans had a number creed as follows:

(1) Limited and unlimited.
(2) Crooked and straight.
(3) One and many.
(4) Right and left.
(5) Masculine and feminine.
(6) Resting and moving.
(7) Straight and curved.
(8) Light and dark.
(9) Good and evil.
(10) Square and rectangle.

A member of the Pythagorean School, Philolaus, states that "all things which can be known have number; for it is not possible that without number anything can either be conceived or known."

It seems likely that the Pythagorean number speculations were partly due to the fact that the units of area and solids were commonly so selected that their edges are linear units and hence numerical relations were seen to exist between magnitudes of widely different characters. Hence the essence of number seemed to lie much deeper than the outward forms of things. It has also been suggested that the deep interest in numbers on the part of the Pythagoreans was inspired by noting that the constellations of the sky may be characterized by the number of visible stars contained therein. At any rate, many of the philosophical speculations about numbers

have been fruitless as far as direct results are concerned. An oasis in this work is furnished by the interest in the so-called Pythagorean triads. Special cases of these were known to the Babylonians at least as early as 4000 B. C., and their study naturally led to the greater Fermat theorem, which has been the source of much fundamental modern work in number theory as well as of many fruitless endeavors.

The ancient Greek mathematicians entered various other mathematical deserts without realizing that they were deserts. The most noted of these are formed by the three great problems of antiquity, *viz.*, the duplication of the cube, the trisection of a general angle, and the squaring of a circle by means of ruler and compass only. It is now known that the last of these is impossible even by means of the most general algebraic constructions while the other two involve the solution of an irreducible cubic equation. Fortunately, their efforts to solve these problems gave rise to a very fruitful study, *viz.*, the study of the conic sections. While exploring these deserts the ancient Greeks incidentally discovered a wonderfully fertile region lying beyond them. They entered this region with great enthusiasm and their wonderful mathematical contributions were crowned by the fruits thereof as is illustrated by work of Apollonius of Perga.

Judging from our modern practices the Greeks entered a mathematical desert even in the noted *Elements* of Euclid where curvilineal as well as rectilineal angles are considered and it is proved that the horn-like angle, *i.e.*, the angle at the point of contact between a circle and a tangent to it, is less than any rectilineal angle. They were thus led to absolutely infinitely small magnitudes since such magnitudes are presented by the differences between the angles at the point of contact formed by different circles which have a common tangent line. Fruitless discussions relating to these horn-like angles were continued during many centuries. An oasis of these discussions is that they exhibit the usefulness of the postulate that all right angles are equal and that they directed attention to a fundamental question in the calculus. It would be difficult to find a more instructive illustration of the nature and usefulness of postulates than the one furnished by the pencil of circles noted above which are supposed to make equal angles with their common diametral line. Instead of saying merely that axioms are self-evident truths, it should also be noted that they may serve to blindfold us, as here, with respect to truths which appear unnecessary for the work in hand.

The mathematical deserts to which we have referred suggest some analogies between the study of mathematics and the cultivation of the soil. Various unusually fertile regions for mathematical study were developed from time to time, and for many centuries students have derived much pleasure and profit from their cultivation. In many cases this cultivation was continued along the lines originally suggested while in other cases there have been radical changes in the methods. Weeds in the form of errors seem to grow up spontaneously in these fields of mathematical study, and most of them can be kept under control by cultivating for the regular crops, but sometimes it seems desirable to devote especial attention to the extermination of weeds. Naturally such a subject as the history of mathematics is especially subject to weeds and hence there is more need of error extermination here than in most of the other subjects. It would be as unwise for the mathematicians to devote all their time to the eradication of error as it would be for the farmers to devote all their time to the extermination of weeds. On the other hand, scien-

tific honesty compels us to use the term weeds for actual weeds irrespective of where they may be growing.

Just as parts of the deserts of the earth have been reclaimed by the construction of irrigation works since very ancient times so parts of the mathematical deserts have been transformed into fertile fields by the construction of ideal elements. As conspicuous examples of such elements we may mention the ordinary complex numbers and the point at infinity. In fact, all pure mathematics may be said to be based upon ideal elements since even the abstract integers are the work of man. Hence the common statement—"God made the integer; all the rest is the work of man"—can not be regarded as literally true. From this it results that all pure mathematics may be regarded as being based upon ideal elements and hence all of it would be a desert if these ideal elements had not been constructed. Some of these ideal elements, such as natural abstract numbers, were constructed in prehistoric times and the fertile regions based thereon may therefore have the appearance of being natural.

The noted German mathematical historian, M. Cantor, in an address before the Paris Congress of Mathematicians, held in 1900, passed over the works of a large number of authors with the following significant remark: "Tous aussi morts que leurs livres; gardons-nous de les ressusciter." A real danger of science is that it will be overwhelmed by its bulkiness and one of the greatest needs of our times is discriminating forgetfulness in accord with this quotation. It is true that even the most discriminating forgetfulness will sometimes entail some loss, but such losses are more than compensated for by the decrease in bulk. In particular, there are hundreds of elementary text-books which make no contribution to knowledge and which should not be allowed to waste the time of all later students of the history of our subject. Complete bibliographies are usually much less valuable than those which include only such works as contributed to the advancement of the subject concerned, but the latter make greater demands on the scholarship of their authors.

Let us be careful not to revive the dead is a note of warning which is perhaps especially needed now in view of the growing interest in the history of science. The rapidly growing richness of this history makes it more and more necessary to select only the best for presentation in a general text-book devoted thereto but it increases the temptation to become bulky. One of the most striking recent discoveries in mathematical history is that the ancient Egyptians used the very fundamental theorem in geometry that the area of a sphere is equal to that of four of its great circles, but they apparently had no proof thereof. It seems therefore probable that this theorem was assumed to be true more than fifteen hundred years before it was proved by Archimedes and thus endowed with much greater intellectual richness. Such discoveries tend to explain why the ancient Greeks went to Egypt and Babylon for their mathematical inspiration.

Mathematical explorations were never pushed with more energy than at present, and it is only reasonable to expect that in the future some of these will be regarded as relating to deserts. As in the past it is to be hoped that in some cases these will be extended beyond the deserts and disclose regions of great fertility while others will probably be abandoned and be remembered only in the history of our subject. Notwithstanding these occasional deserts which have not been reclaimed by irrigation the developments in mathematics stand before us to-day as a great and useful intellectual achievement which gives promise of being greatly extended and of becoming

much more useful. The ancient Greeks seem to have been the first to convert this achievement into real intellectual food by means of demonstrations but earlier people recognized its utility and must have been charmed by such elegant theorems as the one noted above with respect to the area of a sphere.

As far as we know now the pre-Grecian period of mathematical development was one in which little attention was given to proofs and in which only rational numbers were considered. Hence this early mathematics was mainly a mathematics of the desert, and its outstanding developments seem to have been due to the Egyptians and the Sumerians. The ideal element of abstract rational number was introduced during this period, and problems involving the quadratic equation and the use of the Pythagorean theorem were solved. The crowning work of this period seems to have been the recently discovered rules for finding the volume of the frustum of a square pyramid and the area of a sphere. The Greeks introduced a very fruitful ideal element in the form of the irrational and they laid especial stress on proofs, which made it necessary for them to construct systems of postulates. Their mathematics thus become most fruitful and a model for scientific endeavor extending through more than two thousand years. The fact that they entered into some desert regions is of interest, but it should not blind us to the fact that they also developed very fruitful regions so that mathematics is even now sometimes called a Greek science.

THE CONFLICT OF THE PSYCHOLOGIES

By PROFESSOR JOSEPH JASTROW

THE acceptance of psychology in the confederation of the sciences is accomplished. But an internal warfare continues which in historical circumstance is unfortunate and in professional responsibility scandalous. There is no parallel elsewhere. If physicists, chemists or biologists spent as much futile argument in discussing the purposes of their science and held as antagonistic views of the fundamental concepts and direction of progress, that progress itself would be just so far hampered. The state of affairs is not without justification. When the object of research involves the researcher himself, cross lights are inevitable. One is reminded of the myth that Socrates was so strabismic or so introverted as well as so flat-nosed that, in his passion for self-analysis, he trained one eye to look into the other, thus carrying introspection to its experimental extreme. The salvation of all science is its extraverted objectivity—its conviction that things are so regardless of our peculiar insights or outlooks. "Know thyself" may have been a precept in the objective temper; if so, it was promptly counteracted by the subjective presumption: "Man is the measure of all things." Presumably a psychological congress in ancient Athens would have had no more resemblance to a peace conference than a modern one, despite our increasing knowledge of human relations.

It may not be amiss to rehearse the stages by which modern psychology was made possible. In Freudian version the story would be one of decentralizing or deflating the human ego. In the beginning was a superiority complex. Man regarded himself as the center of the universe; a planet that held so noble a creature could be no less than the pivot about which the sun and the cosmos turned. Copernicus and his followers inflicted a harsh blow upon man's planetary dignity; and *"e pur si muove"* has always had to be uttered with hushed breath. When capable of reflection, man sought his future in the impressive stars; nothing was too vast to serve as a medium or a herald of his fate. When the sun no longer rose and set in his honor, he developed the astrological consolation. By the like presumption he made himself the lord of creation, and created gods in his own image. He elevated to the place of consideration that part of his nature that was quite properly his supreme heritage, his immortal soul; he fantasied a paradise for it in the past, a heaven in the future, and from the outset and continuously fell into the hands of the medicine-man who filled his mind with magical ceremonies and glorified mysteries for which the earthly realities were but vicarious or symbolic pathways.

In due course, as truth penetrated despite the resistance offered by the primal urge to self-importance, man's cosmic ego received one traumatic shock after another. He discovered that he was living in one of the minor planets, and that even these did not move in what he regarded as the perfect orbit of the circle, symbolizing his own perfection, but gyrated in such degenerate *Gestalts* as ellipses. He discovered or suspected that the world did not begin with his own creation, but that life, not so dissimilar to his own, preceded it by many eons. The insult of geology and biology was added to the injury of astronomy. His superiority complex suffered under the successive revelations of his insignificance. Evolution inflicted the most unkindest cut of all, the resentment continuing to this day in the fundamentalism of the American wilderness. He had to accept

the genealogy of his anthropoid kin. But through it all, especially in the high seats of academic learning, he clung with tenacity to his philosophical dignities. And if he was declared an apish biped without feathers, he still plumed himself upon the exclusive integrity and unique distinction of his clamorous soul. In his psychological ark, which was to ride high and dry above the scientific inundations, he assembled the instincts in graded animal array, but reserved to himself the gift of reason. His moral urge to perfectionism stood by him. Throughout the ages of shifting darkness and light, he sought the compensations of religion and philosophy, and cultivated the defense mechanisms of morality. He was determined to save his psyche at all costs from the degradations of nature. The supernatural, the mystically natural, the philosophically overnatural, held the stage in turn, and jointly. The last, by its command of the instruments of learning, became the most enduring citadel. There could be no psychology in our modern sense until this slow process of disillusionment was completed.

There are more reasons than this why psychology was late in appearance upon the scientific scene; yet part of the delay resulted from the persistent conflict between the resistance to what was regarded as a mechanistic degradation and the cherished self-determining glorification of human dignity, more and more centrally symbolized by man's reasoning, moralized, possibly immortal soul. In altered temper the conflict continues. The extreme behaviorist insists that the cosmopolitan human herds diving hurriedly into subways and emerging restlessly into skyscrapers are as readily intelligible in their gyrating responses as are rats in a maze seeking what they may devour; while the Freudian analysts maintain that there is no slightest gesture in all this locomotor perturbation that is not complexly animated by vestiges of motives as primal as the sex-ridden cave-man, and as complicated as the urge to security and completion that accounts for the maze-like patterns of civilization.

But it is high time that we should realize that we have fully awakened from this psychological dream. When we pass from its latent meaning thus portrayed in sub-self motives to its patent incidents of plot and circumstance, we find ourselves in a different world alike of interest and of vocabulary. I shall be bold enough to give my own solution first, for I am convinced that all psychology is one no less than is physics or biology, and that the conflicts of the psychologies, so confusing to child study associations, editors of popular magazines, backwater professors of education and the inquisitive laity generally, and likewise so dear to cultist devotees within and without the profession—that this appearance of hopeless division is for the most part illusory, and can be resolved as readily as the famous contradictory description of the elephant by the blind men, one of whom had him by the ears, another by the tail, another by the leg, another by the trunk, and none saw him rightly or whole for lack of eyes to see. For the structural and the functional, the dynamic and the purposive, the introspective and the experimental, the behaviorist and the Freudian, the Gestaltist and the self-psychologist and the other "ism" renderings of the field of mind, are all partial gropings to describe the same beast, as nature made him, and as those whose psychological organs of vision are fully opened can readily see him.

It is obvious to the point of a truism that there is only one psychology, and my stock answer to the persistent inquiry as to what brand of psychology I profess is *naturalistic* psychology. In common with every other psychologist I am a student of human nature, and my first and last obligation is to see that nature as nature made it, and as man has remade it for his own purposes; for that

remaking and that comprehension is the true human glory. The rest is a matter of emphasis, dominance of interest and detail of interpretation. I am convinced that despite their special allegiances the great majority of active psychologists are naturalistic psychologists, and would be willing so to enroll themselves. Science advances not by way of isms but by clarification of concepts. The shifting concept of the human psyche is the core of the history of psychology. The naturalistic concept is established, and thereby sets the course of present-day and all future pursuits.

Still viewing the prospect from our privileged position of clarity and unity, psychology is seen to be the study of the motives and mechanisms of behavior and their organization, and it was never anything else, however mistakenly through presumption or prejudice these motives and mechanisms were misread. The precisionist will insist upon the insertion of the word "mental" before "behavior," and thereby precipitate the unavoidable issue. Unfortunately, the term consciousness became entangled with the ancient dignities as well as with the intraverted strabismic attitude called introspection (from which Professor Bentley vainly wishes to remove the curse by calling it inspection). It still requires a drastic correctional operation to make it plain that this self-awareness is as naturalistic a function as any other. It is in nature's program, and is embedded deep in the evolution of the nervous system. A simple recognition of this naturalization of cerebral function in terms of awareness and all its implications appears in Professor C. Judson Herrick's "The Thinking Machine"—a recent biological version of the essentially human type of behavior. He speaks of the organs of consciousness as readily as of the organs of digestion or the organs of sex, and recognizes in the interplay of those mechanisms the impediments of behavior that may ensue if digestion or sex intrude too constantly upon the domain of consciousness. He makes it plain that without the awareness function, the specifically human gradient of behavior would not have arrived. Consciousness in all its varieties, including subconsciousness and simple orders of sensibility, finds its place in the naturalistic series.

The actual struggle for the establishment of psychology is accordingly the conflict between the pre-naturalistic or anti-naturalistic or super-naturalistic positions versus the naturalistic psychology that has been in the making since Darwin, though it presents previous to that critical era quite an interesting group of antecedents in the story which Baldwin, Dessoir, Brett, Stratton and more recently Gardiner Murphy have presented, and which might well be represented from the approach which I have emphasized. The modern psychologist would be aided and his presumption in turn chastened if he acquired a more intimate historical sense of the story of his profession.

How magical-mystical psychology gave way to a rationalistic view of the human psyche, and how variously it survived and survives, is a tale of significance that runs somewhat parallel and somewhat tangential to the central development with which the historical texts deal. Unfortunately, what is academically central is often not so in the larger view of human interests. Chapter upon chapter must be devoted to the intensive (though to our interests often irrelevant) pursuit of questions of psychological bearing considered in a religious, moralistic and philosophical temper, which for so long made psychology but a subordinate protectorate of philosophy, and infused into it quite alien interests, quite misleading interpretations. The story of all science is full of irrelevancies and false leads, but none perhaps more so than the story of psychology.

The naturalistic psychologist is as prepared as is Watson to reject every vestige of the older approach, but reminds that insurgent behaviorist that this ancient war is over; that there is no purpose in throwing stones at the windows of already deserted houses, however strong the temptation to the small boy that survives even in dignified psychologists.

The other errors of behaviorism à la Watson are more interesting, though perhaps important only in so far as it is more difficult to evolve truth out of confusion than out of error. Evidently we are all behaviorists, but how we interpret our behavioristic obligations may determine largely the trend of our psychological interests. I regret that I may seem to be doing extreme behaviorism too much honor in singling out its extravagances for mention, but it is a fact that this petulant challenge has served the purpose of making responsible psychologists examine their fences and revise their stakes and claims. The dominant and wholesome effect of the naturalistic concept of mind was to divert the overattention to the dignities and lordly prerogatives of the human soul toward the humbler examination of man's communities with the rest of creation and of the simpler beginnings of his mental life. The genetic approach and the broadly zoological approach proved to be variously helpful to naturalistic psychology; so did the physiological approach, demonstrating the organic dependence of so-called higher functions. All this activity, which more than anything else characterizes the modern temper in psychology, has as its central direction the study of psychology from below, of the simpler functions and integrations. The emphasis upon child behavior, upon animal behavior, upon physiological behavior in its psychological integration, is all one consistent expression of the supremely important principle that the simpler, earlier, more intimately organic approach is the indispensable clue to all the varieties of emergent superior functions that equip us to behave like human beings and to misbehave according to the same patterns. It was natural and helpful that with the specialization of psychology, owing to its imperialistic expansion in the last generation, there should be those to whom this "primitive" psychology would make the largest appeal. Taking their clue from the reflexes which form the action pattern of primitive response, some have proposed the name of reflexology, or again, objective psychology, for this domain. I see no worthy purpose in giving this division of naturalistic psychology a special brand. If we continue in that direction we may have to recognize tropismic psychologists and thalamic or visceral psychologists as well as cortical or neo-palliumistic psychologists; and though we shall enrich our vocabulary we shall impoverish our cooperation.

To conclude that because this "primitive" gradient underlies the whole of our psychic life, therefore its pattern dominates the whole of psychology is an error of the first magnitude. Dr. Watson's invitation to psychology to commit harikari under his assurance that the psychologist has no insides to speak of must be politely declined. The conditioned reflex though real is most limited, and the problem of the true behaviorist is to explain how we develop our intelligence by remaining so largely free from conditioning. That the proper appreciation of our "primitive" psychology required an emancipation from the fallacies of our introspective dignities I have made clear; but the transformation of that emancipation into an "ism" is responsible for much of the fallacious appearance of the conflict of our psychologies. Dr. Watson's dramatic execution of consciousness reminds one of Mark Twain's similar response to a similar "religious" stimulus.

Having listened under durance to a sermon on the God-given nature of conscience and the high privileges of that endowment, this skeptical penitent decided that he was much too frail a creature to undergo so severe a strain; so he took his conscience down cellar and killed it with a hatchet. The similar destruction of imagery, of heredity, of insanity, I must on the present occasion decline to take too seriously. I am considering behaviorism and not Watsonian idiosyncrasies. My purpose is accomplished if I can make plain that extreme behaviorism is a radicalistic reaction to the neglect of primitive psychology, and is thus partly responsible for the fallacious conflict of the psychologies.

We may interpret Freudianism as a similar overstatement of cortical psychology to put it neurologically, of spiritual psychology, to put it historically. It is no longer the primitive fear and wonder of our make-up, but a far more sophisticated and perhaps equally strabismic and certainly more harrowing soul introspection that appears in psychoanalysis. A Socratic Freud would be represented as an introverted oversoul suffering from a complex, peering into the subsoul that from its place of repression in the nether regions looks and answers back. Yet the Freudian may claim that such is nature; the only difficulty is to prove it. Its naturalistic intention may be admitted. Observe also how closely these tendencies, and as subconsciously as the complexes which it discovers, turn about those two pivotal phases of the human psyche, its motives and its mechanisms. Freudian psychology is motivation psychology, or motivationism as Troland properly calls this approach; and it discovers its mechanisms in the motivistic temper. So once again, though all psychologists deal with motives and mechanisms, some are primarily motivationists, others primarily mechanists. The behaviorist proposes one set of mechanisms, the Freudian another; and they are not farther apart than are the gradients of the application. What at the one level is called the conditioned response is at the other called (psychic) fixation. We may have brain-stem conditionings and cortical fixations. So far as they validly describe psychic integrations, they are naturalistic.

Again we are fortunate in that as a result of the experimental advances we have come upon an aid to the resolution of this conflict between psychology from below and psychology from above. For we have established a glandular psychology, and have found in its intimate correlation with autonomic functions that nature herself supplies the resolution of the conflict. We are provided with two nervous systems and not one, both alike nature-set; and as we are autonomists or neo-pallic devotees, we shall emphasize our glandular bondage or our cortical self-determination. The danger in assimilating the insight is that of going beyond the evidence. We may be safe in speaking of a hyper-thyroid personality; but if we go on to say that President Harding gave us an adrenal administration and President Wilson a pituitary one, we endanger the quality of our psychological as well as our political affiliations. Naturalistic psychology likewise has its temptations.

And what about the Gestaltist? He is equally naturalistic and turns to the nature-set patterns of behavior for the interpreting concepts of his system. He has introduced a valuable correction of the stimulus-response formula applicable to a wide range of behavior. He has even ventured to find in the analogues of physical constitution a questionable support of his configuration principles. Gestaltung is organization, which in turn is an emphasis upon the total organism affected by the total situation and its total meaning; it is a protest against the detached analyses of an out-

grown psychology. Organization extends from the lowest to the highest. It is inherent in this view to seek the supporting data in the natural range of behavior from low to high, alike in the ascending development of the infantile to the mature, and in the simplest and more rigidly patterned insect behavior to the occasionally rational chimpanzee and the frequently irrational human responses. The Gestaltist has been sanely rational in his claims and on good terms with his colleagues. Repeating the proffered definition of psychology as the study of the mechanisms and motives of behavior and their organization, the Gestalt psychology centers upon the organization.

The menace of the conflicting psychologies is that each will lay claim to the jurisdiction of the whole. By recognizing their common cause in a naturalistic interpretation, the conflict disappears. The day of isms is past; the history of isms is unfortunate. Psychology has come to its own by the same irregular dispensation by which the human mind has found itself, through the outgrowing of the presumptions and the errors of the ages. The story of psychology finds its reflection in the story of each of the sciences. But the unique fact that in this instance the instrument of enlightenment is also the object of study makes the story of man centrally the story of his psychological emancipation.

THE PREEMINENCE OF PRIMARY EXPERIENCE

By J. HOWARD STOUTEMYER

FRANKLIN COLLEGE

JOHN LOCKE, the leading English philosopher of the seventeenth century, affirmed his belief in the ancient dictum, "There is nothing in mind which was not first in the senses," to which his contemporary, Leibnitz, the eminent German philosopher, retorted: "Except the mind itself." In condemning Leibnitz's doctrine of innate ideas which restated Plato's theory that certain universal ideas were part of the original nature of the new-born child, Locke fostered the opposite doctrine that its mind was a blank tablet, and received sensory impressions from the sense organs as materially as the Roman wax tablet received the strokes from the stylus. Put in modern terms, this theory means that mind is changed by sensory stimuli as the film in the kodak is changed when the shutter is opened. Wordsworth, a fellow-countryman of Locke, voiced this static conception of mind in these words:

> The eye—it can not help but see;
> We can not bid the ear be still;
> Our bodies feel, where 'er we be,
> Against or with our will.

The modern point of view holds that mind is inherently active and that it selects, from the myriad sensory stimuli ceaselessly impinging upon the sense organs, those particular ones to which it attends. Hence the sensory stimuli arouse activity that is inherent in mind but in no wise create that activity. As a source of initiating mental responses, the direct participation in life activities, or primary experience, is infinitely more valuable than the memorization of words describing such activities. The following paragraphs propose to illustrate the preeminence of primary experience.

Half a century ago, the late G. Stanley Hall made a study of "The Contents of Children's Minds on Entering School." The results revealed a woeful ignorance of the commonest things. Superintendent Greenwood found similar conditions prevailing among the young children in the schools of Kansas City. Teachers of young children were therefore admonished to take nothing for granted and examine critically the meanings which children attached to their words. Out of the fullness of his experience in a long active life, the late President Eliot wrote:

> It is a matter of everyday experience that most Americans can not observe with accuracy, repeat correctly a conversation, describe accurately what they have seen or heard, or write out on the spot a correct account of a transaction they have just witnessed. . . .
>
> The most important part of education has always been the training of the senses, through which the best part of knowledge comes. This training has two precious results in the individual besides the faculty of accurate observation—one, the acquisition of some sort of skill; the other, the habit of careful reflection and measured reasoning which results in precise statement and record. . . . It follows from these considerations that the teaching of the senses should always have been a prime object in human education at every stage from primary to professional. That prime object it has never been, and is not to-day. The kind of education the modern world has inherited from ancient times is based chiefly on literature.

The ancient Greek ideal of the educated man was "the speaker of words and the doer of deeds." Though the schools gave music for the soul and gymnastics for the body, there were many other educative forces at work developing youth. The great athletic games, the dramatic contests and the

participation in the social and political life of the day secured a harmonious development of the acting, feeling and thinking sides of life attained by no other people.

Since Neo-Platonism taught that the sole source of knowledge came through revelation, the leaders of the Middle Ages withdrew from contact with the world, and hence discouraged the study of nature. With its emphasis on dialectics, scholasticism enforced the verbal memorization of dictations justifying abstract theological dogmas. Absorption in the life to come led to the abhorrence of the beauties of the present world.

Though the Renaissance began as a great liberalizing movement, it soon degenerated into the study of language to the neglect of the message of the literature embodied therein. Since the learner was exalted above the doer, the movement resulted in "gerund-grinding" and the rote-memorization of Latin paradyms. A writer of the time declared: "Youth is deluged with grammar precepts infinitely tedious, perplexed, obscure, and for the most part unprofitable, and that for many years."

As time went on, many educational reformers arose and rebelled against these practices. Rabelais, the French writer, prescribed for Gargantua a wide acquaintance with nature and many constructive activities. His fellow countryman, Montaigne, advocated wide reading of biography, even if it was in Latin, so that youth would come into intimate contact with the great men of antiquity, and wide travel in different countries to learn the customs and traditions of other nations. Then, too, Rousseau, the most brilliant prophet of the eighteenth century, was a firm champion of primary experience. He wrote:

> As everything that enters the mind finds its way through the senses, the first reason of a human being is a reason of sensation; that it is which forms the basis of intellectual reason; our first masters in philosophy are our feet, our hands, our eyes. Substituting books for all this is not teaching us to reason, but simply to use the reason of other people; it teaches us to take a great deal on trust and never to know anything.

Pestalozzi, the Swiss educator, a follower of Rousseau, made the following entry in his diary:

> O God, who art my Father, and the Father of my child, teach me to understand the holy natural laws by which Thou preparest us slowly by means of an innumerable variety of impressions for the conceiving of exact and complete ideas of which words are but the signs. . . . Lead your child out into nature. Teach him on the hill tops and in the valleys. . . . In these hours of freedom, let him be taught by nature. Should a bird sing or an insect hum, at once stop your talk.

The way the child learns from nature is thus described by Whitman:

> There was a child went forth every day,
> And the first object he looked upon that object he became,
> And that object became a part of him for the day or certain part of the day,
> Or for many years or stretching cycle of years.

So the birds and the beasts, the flowers and the fields, the marshes and the hills, and more than all his parents and his friends—

> These became a part of that child who went forth every day.
> And who now goes, and will always go forth every day.

Just as Hiawatha learned of every bird and beast its language and its secrets, so Charles A. Eastman, born in the tepee of a Santee Sioux, learned the woodcraft of his people. Every morning as he "went forth" his uncle would charge him thus:

> "Hadakah, look closely to everything you see." And at evening, on my return he used often to catechise me for an hour or so. "On which side of the trees is the lighter colored bark? On which side do they have the most regular branches?" It was his custom to let me name all the new birds that I had seen during the day. I would name them according

to the color or the shape of the bill or their song or their appearance and the locality of the nest. In fact, anything about the bird that had impressed me as characteristic. He then usually informed me of the correct name. Occasionally I made a hit and this he would warmly commend. He went deeper into this science when I was a little older. He did not expect a correct reply at once to all the voluminous questions that he put to me on these occasions, but he meant to make me observant and a good student of nature.

In a similar way, country children of the last century learned important bits of information incidentally in their everyday experiences. Thus S. S. Goodrich, better known as Peter Parley, compiler of some eighty school texts, secured the best part of his education.

In my youth, I became familiar with every bird common to the country; I knew his call, his song, his hue, his food, his habits; I could detect him by his flight as far as the eye could reach. I knew all the quadrupeds, wild as well as tame. I was acquainted with almost every tree, shrub, bush and flower indigenous to the country. When I have traveled in other countries, the birds, the animals, the vegetation have interested me. In looking over the pages of scientific works on natural history, I have always read with eagerness. Every idea I had touching these matters was living and sympathetic, and beckoned other ideas to it, and these again originated still others. Thus it is that in the race of a busy life, by means of a homely, hearty start, I have, as to these subjects, easily and naturally supplied, in some humble degree, the defects of my irregular education.

Reference may be made here to the effect of nature on the lives and works of a number of the great poets. Alive to every wonder of field and forest, Shakespeare noted carefully "the temple-haunting martlet," "the strange fowl" alighting on "neighbouring ponds," or "the banks whereon the wild thyme grows." Thus he could boast even in boyhood,

> In nature's infinite book of secrecy
> A little can I read.

Blest with genius and a wonderfully rich sensory experience in youth, he was able in manhood to weave them into his imperishable dramas. The clear word pictures in these lines reveal the vividness of sensory images gleaned from wide acquaintance with the flora in springtime.

> When daisies pied and violets blue
> And lady-smocks all silver-white
> And cuckoo-buds of yellow hue
> Do paint the meadows with delight.

It is little wonder that Wordsworth became the harbinger of the nature poets. Born in the small village of Cumberland, he spent his boyhood in the wonderful Lake District where his mind was thrilled with its beauty. His earliest recollections were of the grassy holms and rocky falls of Derwent, and the towering form of Skiddaw. His school days were passed on the banks of Esthwaite Water. What more could be asked in scenic splendor? His appreciation of natural beauty is contrasted with that of the traditional schools as expressed in "Exposition and Reply," where the master scolds William for dreaming his life away:

> Where are your books? that light bequeathed
> To beings else forlorn and blind!
> Up! Up! and drink the spirit breathed
> From dead men to their kind.

In "Tables Turned," William makes answer:

> Books! 'tis a dull and endless strife;
> Come, hear the woodland linnet,
> How sweet his music! On my life
> There's more of wisdom in it.
>
> And hark! how the blithe throstle sings!
> He, too, is no mean preacher;
> Come forth into the light of things,
> Let nature be your teacher.
>
> One impulse from a vernal wood
> May teach you more of man,
> Of moral evil and of good
> Than all the sages can.

Though color-blind and with a poor ear for music, it is surprising how accurately Whittier observed and portrayed

the sights and sounds of the farms about Job's Hill. He knew country life intimately as shown in "Snowbound" and "The Bare-Foot Boy":

> Knowledge never learned of schools,
>
> For, eschewing books and tasks,
> Nature answers all he asks.

Fortunately for Emerson, he was raised in "a quiet open region of gardens and pastures, sunny in winter and shady in summer." Of his life at Harvard, which he entered at thirteen, he wrote:

> The boy at college apologizes for not learning the tutor's tasks, and tries to learn them; but stronger nature gives him Otway and Massinger to read, or betrays him into a stroll to Mount Auburn, in study hours. . . . Ah, the powers of the Spring, and ah, the voice of the bluebird and the witchcraft of Mount Auburn dells in those days.

Thus in "Good-bye" he wrote these delightfully refreshing lines:

> O, when I am safe in my sylvan home
> I tread on the pride of Greece and Rome;
> And when I am stretched beneath the pines,
> Where the evening star so holy shines,
> I laugh at the lore and the pride of man,
> At the sophist schools and the learned clan;
> For what are they all, in their high conceit,
> When man in the bush with God may meet?

In "May-Day" also he reveals his keen appreciation of nature's spell:

> If I could put my woods in song
> And tell what's there enjoyed,
> All men would to my garden throng,
> And leave the cities void.
>
> Can'st thou copy in verse one chime
> Of the wood-bell's peal and cry,
> Write in a book the morning's prime,
> Or match with words that tender sky?
>
> Ever the words of the gods resound;
> But the porches of man's ear
> Seldom in this low life's round
> Are unsealed that he may hear.
>
> But the meanings cleave to the lake,
> Can not be carried in book or urn;
> Go thy ways now, come later back,
> On waves, and hedges still they burn.

The early influences of the beauties of nature are clearly shown in the writings of Longfellow. His birthplace, Portland, was a beautiful city full of trees, with the ocean in front, while in the hinterland rose the low hills of Munjoy and Bramhall deeply wooded. In manhood, he wrote:

> Often I think of the beautiful town
> That is seated by the sea;
> Often in thought go up and down
> The pleasant streets of that dear old town,
> And my youth comes back to me.
> . . . . . .
> I can see the shadowy lines of its trees,
> And catch, in sudden gleams,
> The sheen of the far surrounding seas,
> And islands that were the Hesperides
> Of all my boyish dreams,
> . . . . . .
> I remember the black wharves and the slips,
> And the sea-tides tossing free;
> And Spanish sailors with bearded lips,
> And the beauty and the mystery of the ships,
> And the magic of the sea.
> And the voice of that wayward song
> Is singing and saying still:
> "A boy's will is the wind's will,
> And the thoughts of youth are long,
> long thoughts."

With these ever-recurring voices of youth, it is little wonder that he wrote these fascinating lines on the influence of nature in his poem for the celebration of "The Fiftieth Birthday of Agassiz," the leading naturalist of the time.

> And Nature, the dear old nurse, took
> The child upon her knee,
> Saying: "Here is a story book
> Thy Father has written for thee.
>
> Come wander with me," she said,
> "Into the regions yet untrod;
> And read what is still unread
> In the manuscripts of God."
>
> And he wandered away and away
> With Nature, the dear old nurse,
> Who sang to him night and day
> The rhymes of the universe.
>
> And whenever the way seemed long,
> Or his heart began to fail,
> She would sing a more wonderful song,
> Or tell a more wonderful tale.

From these selections, taken as types, we conclude that the poets believed that contact with nature was an educative force of prime importance. What then is the place of the book? In "The American Scholar," Emerson gives an excellent answer:

> I had better never see a book, than to be warped by its attraction clean out of my own orbit, and made a satellite instead of a system. Hence, instead of Man thinking, we have the bookworm. Hence, the book-learned class, who value books, as such; not related to nature and human constitution, but making a sort of Third Estate with the world and the soul. Man thinking must not be subdued by his instruments. Books are for the scholar's idle times. When he can read God directly, the hour is too precious to be wasted in other men's manuscripts of their readings. But when intervals of darkness come, as come they must, when the sun is hid, and the stars withdraw their shining, we repair to the lamps which were kindled by their ray to guide our steps to the East again, where the dawn is.

Thus to Man thinking, books become the beacons that beckon on to new vistas of adventure. In "Great Naturalists" Henry F. Osborn states the influence of Malthus on Darwin and Wallace. Darwin wrote thus:

> In October, 1838, that is fifteen months after I had begun my systematic inquiry, I happened to read for amusement, "Malthus on Population," and being well prepared to appreciate the struggle for existence which everywhere goes on, it at once struck me that under these circumstances favorable variations would tend to be preserved and unfavorable ones be destroyed. Here, then, I had at last a theory by which to work.

Though he gleaned little benefit from his college work, he profited much from reading Shakespeare, Wordsworth, Coleridge and Milton. He prized greatly the associations with such men as Herschel, Humboldt, Henslow, and above all the great geologist Lyell. The most dominant and dynamic forces of his whole life, however, were the years spent on the voyage of the *Beagle* which fruited twenty-one years later in "The Origin of Species." Wallace had read the same stirring books, and felt the spell of these same scientists. Four years spent along the Amazon, and, later, eight years in the Malay Archipelago, afforded him the materials to bolster up the same theory of evolution which had come to Darwin twenty years earlier. In both cases, wide travel garnered great trains of facts and observations, but an adequate theory to explain these came from the reading of Malthus's "Essay on Population." The book was certainly important, but its seed would have fallen on barren soil had not wide experience in dealing with natural phenomena already tilled it.

In his essay "Boy Life in a Country Town," G. Stanley Hall describes the educative situations in a Massachusetts town at about the middle of the nineteenth century. In the regular activities in home and community, the boy learned the rudiments of some sixty trades, and doubtless the girl learned quite as much in the duties of home-making. Children freely associated with other children throughout the neighborhood. They engaged in all the sports and games of the country side. Then, too, there were the husking bees, quilting parties, spelling schools, and many other types of social gatherings where the boy and the girl gained social insight. The value of the primary experiences in dealing with the whole processes of clothmaking—shearing the sheep, carding the wool, plying the loom—and fashioning the cloth into garments, or the making of tools, building homes and animal husbandry, is thus strikingly portrayed by Professor John Dewey:

> We can not overlook the factors of discipline and of character-building involved in this: Training in habits of order and industry, and in the idea of responsibility, of obligation to do something, to produce something, in the world. There was always something which needed to be done, and a real necessity that each member of the household should do his own part faithfully and in cooperation with others. Personalities which became effective

in action were bred and tested in the medium of action. Again, we can not overlook the importance for educational purposes of the close and intimate acquaintance got with nature at first hand, with real things and materials, with the actual processes of their manipulation, and the knowledge of their social necessities and uses. In all this there was continual training of observation, of ingenuity, constructive imagination, of logical thought and of the sense of reality acquired through first-hand contact with actualities. The educative forces of the domestic spinning and weaving, of the sawmill, the grist-mill, the cooper shop and the blacksmith forge, were continually operative.

No number of object-lessons, got up *as* object-lessons for the sake of giving information, can afford even the shadow of a substitute for acquaintance with the plants and animals of the farm and garden, acquired through actual living among them and caring for them. No training of sense organs in school, introduced for the sake of training, can begin to compete with the alertness and fulness of sense-life that comes through daily intimacy and interest in familiar occupations. Verbal memory can be trained in committing tasks, a certain discipline of the reasoning powers can be acquired through the lessons in science and mathematics; but, after all, this is somewhat remote and shadowy compared with the training of attention and of judgment that is acquired in having to do things with a real motive behind and a real outcome ahead.

Within a century our population has drifted from rural regions to urban centers so that now more than 50 per cent. of the people live in cities of 2,500 or more. With the development of machine processes of manufacture, many educative situations in home and community have gone to large manufacturing plants. Thus one by one these primary experiences have been taken away from the child. In lieu of these educative situations, school programs have been enlarged, new subjects have been added, and larger text-books have been adopted. Thus children, having lost by natural means their chances for actual work and play, fail to develop depth of emotions and breadth of knowledge about things, for they do not have opportunities to come into intimate contact with nature or to make things or to care for pets or to have responsibilities or tasks. Multitudes, flowing into cities built by a sturdy by-gone generation, are confused thereby for they can not understand the forces that are overpowering them. They are rushed from place to place, jerked down subways, and shot up elevators; they climb stairways by machinery, whisk lunch off of moving tables, and wonder if the North Star is still fixed.

Three quarters of a century ago, Herbert Spencer, the English philosopher, wrote that parents forced books upon children too early, for they did not recognize the superior importance of first-hand facts in experience to second-hand facts in books, and they failed to realize that book materials could be understood only through direct contact with things treated in these books. He wrote thus:

Possessed by a superstition which worships the symbols of knowledge instead of knowledge itself, they do not see that only when his acquaintance with the objects and processes of the household, the street and the fields, is becoming tolerably exhaustive, only then should a child be introduced to the new sources of information which books supply, and this, not only because immediate cognition is of far greater value than mediate cognition, but also because the words contained in books can rightly be interpreted into ideas only in proportion to the antecedent experience of things.

About a third of a century ago the eminent educator, Paul Hanus, criticized the isolation of the school from life and asserted that the methods of teaching the common branches were so bookish and abstract that children failed to make permanent mastery of their contents.

It was, therefore, quite generally true that the total permanent result of the first eight years of the pupil's school life was the ability to read, but not the reading habit; the ability to spell and write words, but no power of expression with the pen; a varying ability to add, subtract, multiply and divide simple numbers, integral and fractional, but much uncertainty in

all other arithmetical operations; a fragmentary book knowledge of names and places of our own country and of foreign countries; and some scrappy information relating to the history of the United States.

Since schools so frequently taught shreds of knowledge torn from their contexts, it is little wonder that pupils failed to comprehend these abstractions. Answers to examination questions, as the following, reveal such lack of intelligent mastery:

Wolfe declared he would rather repeat Gray's "Elegy" than take Quebec.

The Rosetta Stone was a missionary captured by the bandits.

The imperfect tense is used in French to express a future action in past time which does not take place at all.

Much butter is imported from Denmark because Danish cows have greater enterprise and superior technical education to ours.

It has happened that pupils living on the Mississippi River failed to identify it with the one studied in the geography. Quick, an English educator of the past century, asked a group of boys to locate Rome. Since none answered, he said, "It's geography." They immediately said, "In Italy." Some Boston school boys read "Wisconsin" on the badge of a traveler. When he asked where Wisconsin was, the boys were puzzled. The traveler exclaimed: "What? Haven't you studied geography?" They answered quickly, "You mean the Wisconsin in the geography; that's one of the forty-five states." A high-school graduate was surprised to discover that the Caesar of Latin and the Caesar of history and the Caesar of English literature were one and the same man.

As long as the home gave training in the manual skills and the community afforded educative situations in orienting youth, there was no great danger from the isolation of the school from active life, and the imperfect mastery of the materials taught. With the increasing complexity of social forces and the consequent lessening opportunities for participation in the fundamental community activities, the schools must compensate for these losses by affording means of vicariously participating in these activities. They must help the child to organize his world and to orient himself in it. "To see life clearly and see it whole" is an important function of the school. What Howard R. Driggs discovered in regard to cities should be the experience of every child in the larger world of things. He and his brother went to Chicago in 1893 to see the World's Fair. They were as much lost in the large city as were the "babes lost in the woods." By chance they met a friend who told them to go to the top of the Masonic Temple and look over the city.

As we walked around the observatory platform, the city in all its settings spread itself like an animated map before and below us. Out to the east, Lake Michigan; to the south, west and north, the checkered mass of business blocks and other buildings spreading far away over the Illinois prairie. The whole plan of the city was revealed in one bird's eye view. Since that sight I have never been at a loss to direct myself in Chicago. And since then, too, whenever I visit a large city for the first time, I always try to get to the top of some hill or skyscraper and take in the city as a whole.

Schools are attempting this orientation by introducing general courses in science, language, mathematics and literature. Educational guidance and vocational guidance are also helpful for this purpose.

The schools are also slowly changing their methods of teaching to secure this end. Problem-solving replaces the extreme emphasis on memory work in the older education; conduct is an end far more sought after than isolated information; principles are developed as problematic situations require their use; and school situations duplicate life situations as far as that can be accomplished. Field trips, pageants, dramatization, and other like devices make real many of the school materials of older days. A third of a century ago, Professor Dewey intro-

duced into the University of Chicago Elementary School a kind of approach which he called "Occupations." An abridged statement of his philosophy follows:

> By occupation, I mean a mode of activity on the part of the child which reproduces, or runs parallel to, some form of work carried on in social life. The fundamental point in the psychology of an occupation is that it maintains a balance between the intellectual and the practical phases of experience. As an occupation it is active or motor; it finds expression through the physical organs, the eyes, hands, etc. But it also involves continual observation of materials, and continual planning and reflection, in order that the practical executive side may be successfully carried on. Now in the natural life of the individual there is always a reason for sense-observation. There is always some need, coming from an end to be reached, that makes one look about to discover and discriminate whatever will assist him. Normal sensations operate as clues, as aids, as stimuli, in directing activity in what has to be done; they are not ends in themselves. The same principle applies to normal thinking. It also does not occur for its own sake, nor end in itself. It arises from the need of meeting some difficulty, in reflecting upon the best way of overcoming it, and thus leads to planning, to projecting mentally the result to be reached, and deciding upon the steps necessary and the serial order. This concrete logic of action precedes the logic of pure speculation or abstract investigation; and through the mental habits that it forms it is the best preparation for the latter.

The several activities necessary for the securing of food, transportation of these necessary food supplies, weaving and cloth-making, tools and their uses and many other processes actually used in out-of-school life formed the basis of their study, not as trade information but as a means of understanding life activities. Following Professor Dewey's lead the reorganized schools of Russia devote much of the first four years of school life to the study of the village activities surrounding the child. The elements of mathematics, geography, civics and history are introduced as they help to interpret the social and economic life of the village. In "Schools of Tomorrow," Dewey describes a number of schools that are attempting to introduce activities in order that, by means of participation, the child may see life clearly and as a whole. Although schools of private adventure and experimental schools in universities have taken the lead there are numerous public schools that are quietly pushing toward this goal. The Junior Republic at Freeville, New York, called "an experiment in democracy," has attempted to duplicate all the activities that an ordinary community pursues. The juvenile citizens work and receive their wages; they perform the duties of several civic offices, and, by means of this participation, they master the necessary skills, knowledges and emotional sets for good citizenship in their own republic. Perhaps the most spectacular of all the attempts to get experience first hand is the floating university. Students of botany and zoology have rare opportunities for study at the botanical gardens in Java and Ceylon, the aquariums at Honolulu and Naples, and the zoological gardens in Hamburg and London. Students of the social sciences have just as rare opportunities in studying the different races, their customs and traditions.

Life is full and vast in proportion to the fullness and vastness of the life of the persons experiencing it. So too, the book is significant in proportion to the significance of the experiences that the reader brings to interpret the ideas of the author. Hence, book learning and school work must be based on primary experiences, must interpret them and finally lead to a clear and whole view of life.

SCIENCE AND IMAGINATION

By Professor WARREN WEAVER

UNIVERSITY OF WISCONSIN

THERE is little novelty in the statement that mathematics is the essence of science, and almost as little novelty in the statement that mathematics is an art. That mathematics plays the premier rôle in science is, in fact, an old notion, and one which has found frequent expression ever since the time of Pythagoras' famous and prophetic dictum that the nature of things lay in number. So common has it been for scientists and philosophers to comment on this dependence that the problem of adducing suitable quotations is distinctly one of selection, rather than search. Only two quotations will be given here, one from a preeminent scientist and one from a great philosopher. In Laplace's essay on probabilities occurs the statement, "All the effects of nature are but mathematical results of a small number of immutable laws"; while Kant has said, "I contend that each natural science is a real science only in so far as it is mathematics."

Not so ancient or so generally held is the notion that mathematics is an art. Even near the end of the twentieth century Boltzmann, describing some memoirs of Kirchoff, spoke of these mathematical essays as having uncommon beauty, and then felt it necessary to add, "'Beauty?' I hear you ask: 'Do not the graces flee where integrals stretch forth their necks?'" Shortly after 1900, however, one of the great American mathematicians said, "I like to look at mathematics almost more as an art than as a science"; while from Bertrand Russell we have the statement, "Mathematics, rightly viewed, possesses supreme beauty—a beauty cold and austere, like that of sculpture."

Thus the statements, "Mathematics is the essence of science" and "Mathematics is an art," are by no means new statements. We would scarcely expect that any such simple, natural and general pronouncements would have escaped previous expression. Mathematicians have a professional reason for being particularly skeptical concerning the probable novelty of any such statement, for they may easily reckon that, if four words be chosen from the dictionary at random, the chance production of the sentence, "Mathematics is an art," is a million million million times more likely than is the dealing of any particular hand around the bridge table. The topic under consideration is, thus, an old one, but one which deserves continual reexamination as our attitude toward mathematics and science changes. And the time now seems particularly appropriate for such examination, since our views of the purposes and possibilities of scientific theories are in the process of so fundamental a change. The previous sentences have referred, in general, to "science," but further consideration will, for several reasons, be restricted to physics. This is not, it would seem, an essential restriction. The restriction exists partly because physics is the most completely developed science, and partly merely because the writer is not qualified to speak of other fields of science. Physics, however, deserves and can bear this special attention. It is surely a basic science; it is probably fair to pronounce it the basic science. John Dewey has recently expressed the dependence of all other sciences on physics by remarking, "Chemistry waited on the advance of physics; the sciences of living

things required the materials and methods of physics and chemistry in order to make headway. Human psychology ceased to be speculative opinion only when biological and physiological conclusions were available."

It is thus our purpose to consider the relationship between physics and mathematics, and that between mathematics and art; and, more particularly, it is our purpose, as the title suggests, to point out the rôle which imagination plays in the development of mathematics and physics. A double thesis will be defended. It will be argued that mathematics, as we view it to-day, is an artistic production of the creative imagination; and it will be argued that physics is to-day in the process of becoming almost purely mathematical in structure.

It has become quite fashionable, of late, to speak of the beauty of mathematics and to refer to mathematics as an art. It may seem somewhat ungracious to point it out, but such statements have frequently been made by persons who certainly do not know what mathematics is, and who very possibly do not know what art is. It is dangerously attractive for one to make such gestures, courteous though they be, towards that which one respects and admires, even though he neither appreciates nor understands. Grandly to say that mathematics is an art, carries with it a pleasant implication that the speaker, in the slanguage of to-day, "Knows his mathematics" and "Knows his art." Thus this statement has sometimes been one of those rebounding compliments whose real purpose is to reveal the erudition and culture of the maker. There is fairly close agreement among mathematicians as to the nature of their subject, but when we speak of art, we must proceed with caution and reserve, well aware that there are as many definitions of art as there are thinking men.

It will be necessary, in the first place, to remind ourselves of a few familiar facts concerning mathematics itself. The first great organization of mathematics occurred in Greece in the few centuries immediately preceding the birth of Christ. This organization is epitomized in the writings of Euclid. The Greek geometers recognized clearly the necessity that mathematics, as a logical structure, start somewhere, and they exhibited, at the outset of their arguments, the primitive concepts or elements which the argument was to concern and the primitive propositions or axioms concerning these elements. The primitive elements of their geometry were such things as "points," "lines," "planes," etc. These elements were, to them, entities which were so well known and so widely recognized as to need little description. They said, for example, that a "point" was that which had no dimensions, not because they thought that this remark uniquely and completely defined what they meant by points, but merely to indicate to the reader that by the word "point" the writer meant that familiar dimensionless object which the reader was himself accustomed to call a point. That is, the so-called "definitions" of the elements were relatively vague and informal remarks, whose real purpose was merely to identify the concepts in the writer's mind with concepts the reader was assumed already to possess. The "axioms" were, to them, self-evidently true statements about the familiar elements. That their statements concerning the elements were for the purpose of identification rather than of definition is clear from the fact that the axioms were supposed self-evidently true. A statement can not be viewed as self-evidently true unless it concerns familiar, rather than new concepts. Granting the familiar elements and certain self-evidently true relations between them, the Greek mathematician then carried out logical arguments which resulted in interesting further relations, called

theorems. The significant feature of this structure is the clear recognition of the necessity for an explicit and accepted basis of fact and concept, it being the task of the mathematician to discover all the relationships which are logical consequences of this basis.

It took mathematics roughly twenty centuries to materially improve on this conception. It is true that for centuries there had been vague misgivings concerning the axioms of Euclid. The famous seventh axiom concerning the number of lines that can be drawn through a point parallel to a given line, did not, even to men of that day, have quite the clear ring that a self-evident truth should have. Mathematicians, logicians, philosophers and theologians (this was back in those ripe days when party lines were not so strictly drawn) investigated this axiom, attempting to show that it was a logical consequence of the other more obvious axioms. These attempts consistently failed. Finally, in 1733, a geometer and logician named Saccheri attempted to show that any departure from this axiom would lead to inconsistencies. To his surprise, the inconsistencies did not develop. It is important to notice that, although this particular axiom was under close scrutiny, its truth was not suspect. It was still held that axioms should be self-evident truths; the only difficulty was that this particular axiom seemed unsatisfactory. The impetus for the real change in view-point came from the geometrical writings, published shortly after 1825, of Lobachefski and Bolyai. The old naïve belief that the postulates of Euclid were self-evident truths, or that the less evident ones were capable of proof on the basis of the more evident ones, was completely overthrown by the fact, established independently by these two geometers, that it was possible materially to alter these postulates and logically derive new bodies of doctrine, just as self-consistent and as inherently plausible as the old. The theories these two great geometers inaugurated are the so-called non-Euclidean geometries which have played so significant a rôle in the development of the theory of relativity. A second great impetus came from the work of Weierstrass, Méray, Dedekind, Cantor and later mathematicians concerning the relationship between analysis and the theory of the integers.

Without stopping to trace the steps by which the change in view-point has occurred, one can summarize the result in this way: A branch of modern mathematics, like Greek geometry, consists of the logically consistent consequences of an original set of propositions about an original set of elements. Our ideas, however, concerning these original propositions and elements have experienced great change. The original propositions we no longer call axioms and regard as self-evident; we call them postulates, and regard it to be without meaning to inquire concerning their truth. The original elements we no longer "define" or describe in the hope that the reader will recognize them. The elements of a modern theory are quite undefined, except in so far as one may view as a defining qualification the statement that the elements satisfy the postulates.

Thus modern mathematics differs essentially in structure from the mathematics which prevailed up to the nineteenth century. Granted the postulational basis, modern mathematics proceeds in much the same way as did the older discipline. The problems have become more involved and more subtle, so that the logical technique required is more extensive and delicate. The fact that the mathematician is perfectly free in his choice of postulation basis brings into mathematics some questions of a quite new nature. As regards our present argument, however, the important

point is that the new attitude towards the beginning of mathematics has brought with it an entirely new attitude towards the subject as a whole.

There are two chief aspects of this new attitude. The first results from the fact that the postulational (rather than axiomatic) character of modern mathematics entirely severs the previous supposed connection between mathematics and truth, and replaces this by the less pretentious but more definite quality of logical consistency. The Greeks naturally viewed their theorems as true, since they were the logical consequences of self-evident truths; but the postulates of a modern theory, far from being self-evident truths, are pure assumptions and have no concern with truth at all. Mathematics does not even understand the question "Is this statement true?" but concentrates her powers solely on attacking, with truly awful rigor, the question "Is this statement tautological?" To those not versed in mathematics this is a startling admission, for the "man in the street" has a profound and almost mystic respect for what he thinks of as the "truth" of mathematics. When the popular orator wishes to reach the pinnacle of finality, he thunders out that something is "mathematically true." He intends to thus convey, and usually does convey, the idea that it would be nothing short of indecent insanity to doubt his statement. But it is important to see that when the man in the street views mathematics as a subject austerely true, he ascribes to mathematics a virtue she not only does not claim, but the existence of which she does not even recognize.

A second particularly important feature of the new attitude towards mathematics is the great increase of significance which has resulted from the lack of definition of the elements. The theory is no longer merely a theory concerning particular things which behave in a certain way, but rather a general theory concerning all things which behave in this way. For example, since Weierstrass and Cantor have shown us that all analysis is reducible to statements about integers and since Peano has shown us that the theory of integers is a special instance of the general theory of any infinite sequence satisfying a few simple postulates, we now appreciate that any theorem of analysis can be interpreted in terms of such general sequences. To take a more striking example, the postulates at the base of the Dirac's abstract formulation of quantum theory are, with a minor change, those used in general theories of linear sets. Thus the theorems of this abstract branch of pure mathematics are (with suitable modification) theorems of quantum theory.

It is with all seriousness, then, that one of the leading authorities defines mathematics as the subject in which we never know what we are talking about, or whether what we are saying is true. Just preceding this famous definition, Mr. Bertrand Russell said:

> Pure mathematics consists entirely of such asseverations as that, if such and such a proposition is true of anything, then such and such another proposition is true of that same thing. It is essential not to discuss whether the first proposition is really true, and not to mention what the anything is of which it is supposed to be true. If our hypothesis is about anything, and not about some one or more particular things, then our deductions constitute mathematics.

Having gone thus far, it will be well, before proceeding with our main argument, to barely mention certain important considerations with which we will not be concerned. It would be unfortunate to leave the impression that the two aspects of newer mathematics just discussed are its only distinguishing features. The new attitude has brought new problems of great significance, and has been responsible for great advances

not hinted at above. For example, if one's original assumptions are self-evident truths, then they naturally are consistent; but if they are pure assumptions, one has an important task, namely, that of developing the logical mechanism for scrutinizing a set of assumptions relative to their reducibility and consistency. Furthermore, the new mathematics has developed a standard of rigor quite unprecedented. The influence of this new standard of rigor on thought in general, and even on logic itself, has been very great, but can not be discussed here. We are apt to think of the assistance mathematics has lent to astronomy, physics, the engineering sciences, etc., as being the greatest monument to her usefulness, but it may well be that the greatest debt that progress will eventually owe mathematics will be due her for the cleansing and purifying honesty she has insisted upon in all intellectual processes. One who was, so to speak, raised on undefined elements, is not likely to be deluded into a false sense of understanding when there is presented to him an argument which turns on a supposed understanding of concepts actually quite vague and undefined, but which, from mere long usage, we have regarded as familiar. One who was trained in the school of postulational method realizes keenly that an "explanation" in any intellectual field is the setting forth of the connection between two logical levels—a higher or more complex level, on which is the matter to be explained, and a lower or more simple level, on which are found the terms of the explanation. And since explanations are of this sort, it is clear that the sense and value of the explanation is vague if not altogether absent unless the lower as well as the higher level is specifically scrutinized.

Important as are the considerations just mentioned, they are not our principal concern here. We are now in a position to defend our first proposition, "Mathematics is an art," and we shall see that an appreciation of the spirit of modern mathematics is essential to the discussion. The point of central significance seems to be this: The purely assumptive character of modern postulational mathematics makes it clear that a mathematician is not a discoverer, but a creator. To be sure, not all that is created is art; but it would surely seem that no activity has a right to enter the contest for recognition as artistic activity until it can first establish itself as creative activity. The mathematician is not merely the industrious janitor of a dark and dirty room, grubbing about in the corners in the hope that he may finally uncover and dust off a preexisting truth. He is engaged in the far more exciting task of exercising his own creative imagination, and of creating complicated logical patterns of great beauty. In the early stages of photography, the operator was essentially a discoverer. He went about locating faces or objects or scenes which he caused his apparatus to duplicate with slavish accuracy. Photography became an art when the operator came to realize that he need not limit himself to the discovery and duplication of existing forms and scenes. He found that he could use soft focus lenses, and that he could so manipulate his developing and printing processes as to bring the whole result under his conscious and selective control. Quite similar has been the experience of the mathematician.

It is difficult to say what it is that decides whether or not a creation is a work of art. It seems to be largely a matter of the subjective reaction which the creation arouses; but it will be dangerously easy to argue in terms of subjective reactions. When a man reads a paper by Einstein, and then goes about beating his breast, tearing his hair and declaring that the paper is a great

work of art, we are not so likely to agree with him as we are to suspect that he is a bit balmy. If thousands of respectable citizens were to read the paper, and were universally struck by its artistic qualities, then we might be ready to accept the evidence of such a subjective reaction. But, unfortunately, mathematics is a very exclusive discipline, written in a condensed jargon which it takes years to master, and it can never hope to gain general direct appreciation. So we will do well to confine our argument almost entirely to objective qualities of mathematics, although this is an obviously severe limitation.

We may first consider certain similarities between the actual procedure of the mathematician and artistic workers in other fields. When the mathematician has finished one task and is looking about him for a new one, the situation that confronts him is very similar to that which would confront a painter or a poet under similar circumstances. Neither is a mere explorer or discoverer. Each is a potential creator. Each has before him a choice of media. He may choose the sonnet form, the language of geometry, the sculptor's chisel, the algebraic approach, the etcher's needle, the tensor method or what he will. His medium chosen, his subject is itself restricted only by the bounds of his imaginative faculty. He may choose a homely and familiar scene, as do the genre painters and as do some mathematicians. Or he may cut as loose from tradition as did Blake, Grassmann, Picasso and Einstein. In the development of his subject, each may owe to external nature as detailed a debt as he chooses. He may seek to imitate nature meticulously and microscopically, as did certain of the Dutch masters and as does the theoretical physicist of to-day. Or the mathematician may create logical patterns as purely unimaginative as the geometrical pattern of the designer of rugs or fabrics. He may even let his imagination run riot, as do the most bizarre of modern painters and poets, and as mathematicians have often done. Having chosen his medium, subject and style, the activity of the mathematician is subject to a sort of artistic restraint, as is the activity of a sculptor or poet. He experiences a limitation of means which seems to be a basic characteristic of any artistic process. The mathematician has to use (at least ordinarily) the canons of logic, just as the poet has to use (ordinarily) accepted language. Unless he is a truly great pioneer, the mathematician is limited by the traditions of his subject. Such limitations, however, are characteristic of the restraint of any decent art. One does not write a sonnet of twenty lines, nor does he carve a marble and then touch it up with oil paints.

The actual activity of the mathematician thus shows striking similarity to the activity of the composer, the poet or the painter. As regards the product of the mathematician, it is more difficult to say what it is that makes those judge it to be artistic who appreciate it at all. There are, however, certain qualities of a fine piece of mathematics which permit description in terms familiar to any one. For example, there is, to mention first a less important point, the evidence of mastery of technique. There is the artistic quality of condensation or concentration of significance. This is a familiar enough quality in all recognized art forms. The clearest illustration, perhaps, comes from poetry, where one beautiful line often contains as much as a whole prose essay. Similarly, mathematics, using as a containing vessel for the thought a powerful notation, distills off the lighter vapors of minor significance, and obtains a residue which is largely unencumbered by non-essentials. An inner simplicity is a characteristic of much art and of much good mathematics—not, to be sure, mere lazy sim-

plicity that results from considering only a simple situation, but the successful simplicity that is hardly won. Furthermore, great mathematics, like any great art, has an implication beyond the obvious. It grows on one in importance and significance as he ponders over it. Illustrations of this, in mathematics, are almost too well known to deserve mention. The non-Euclidean geometry and the absolute differential calculus of one generation is used in the relativity theory of the next. The theory of groups, long viewed as one of the most abstract theories of pure mathematics, now turns out to be fundamental in atomic theories. The quality, however, of mathematics which seems of greatest artistic significance is its universality. It has been noted above that one of the distinguishing features of modern mathematics is the lack of definition and consequent generality of the elements of the theory. There is, to be sure, art which refers to the particular; but that which adequately treats of the universal is, *ipso facto,* art.

Any one who has experienced the esthetic thrill which mathematics can induce realizes the inadequacy of these statements. He knows that mathematics not only has beauty, but that it is a pure beauty of relation and structure, condensed and unified in its expression, unsuspectedly rich in its implications and universal in its significance. He knows that the mathematician is that emancipated sculptor who deals in form freed of substance.

Thus there is good reason to believe that mathematics is an art, and that the creative imagination plays a dominant rôle in the development of that art. It remains to see the extent to which physics has become mathematical. In the first place, physics is a preeminently quantitative science, having concern only for that which is measurable. It is thus evident at once that mathematics is germane to all the legitimate considerations of any physical theory. The aim of physics is to "explain" the measurements which result from experiment. The theoretical physics which explains the experimental result is nothing more or less than a body of mathematical doctrine to which is added, as an essential part, a physical interpretation of the abstract terms of the theory, this interpretation arising from an identification of certain concepts of the theory with certain measurable physical entities. When once a physicist has identified concepts of a pure mathematical theory with certain physical entities, he then has a right to ask, "Is this mathematico-physical theory true or is it not?" That is, do the actual measurements of the physical entities satisfy the relations of the theory? A physicist, therefore, is precisely a man who, by particularizing and materializing the elements of a mathematical theory, earns the right to ask that previously forbidden question, "Is it true?"

The rôle which mathematics has played in physics has been, in considerable measure, governed by the views that have been held, at various times, concerning the subtle process by means of which a theory explains the phenomena it concerns. Physical theories seem to explain facts in two chief ways, by analogy and by simplification. To illustrate these two types of explanation, consider the familiar example of the kinetic theory of gases. A gas, it is found, exerts a pressure on the walls of a containing vessel which is the same as would be the average force of bombardment due to a vast horde of tiny, perfectly elastic spheres buffeting their ways about in the vessel. This furnishes a mental picture to have before us, and when we further discover that many of the macroscopic properties of the gas are "explainable" on the basis of applying the familiar laws of dynam-

ics to these numerous elastic spheres, we feel that this is a satisfying theory which does indeed "explain" the facts. To most physicists this theory probably explains partly by analogy and partly by simplification. To the extent to which one believes that he now understands the pressure due to a gas because he previously understood the mechanics of perfectly elastic collision, to this extent the theory explains by analogy. To the extent, however, that one feels the real value of this theory to be the correlating of surprisingly diverse phenomena on the basis of comparatively meager assumption, to that extent the theory explains by simplification. To consider one more example, electrodynamical theory as formulated in the Maxwell field equations was probably viewed by Maxwell himself to explain largely by analogy, since he laid great store by the mechanical models which aided him in developing the theory. At the present time, however, we judge this theory to explain almost solely by simplification. There is neither time nor need to argue here that explanations by analogy are losing popularity, and that there is a fast-growing tendency to regard with actual distrust the suggestions that come from the use of models. The mathematician will realize at once that explanation by analogy bears a close relation to the structure of Greek mathematics, in that it expresses new and complex facts in terms of the familiar and the supposedly self-evident. It is clear that such explanations are but postponements of that evil day of reckoning when some skeptic will question further. One of the most unfortunate aspects of the model theories of physics, moreover, arises from the chronological fact that the old and hence familiar concepts of physics, in particular, the concepts of mechanics, are not, from our present point of view, fundamental concepts. One finds those who still attempt to explain the basic science of electrodynamics in terms of those mechanical concepts which, although they are old and falsely familiar, should, in fact, emerge from electrodynamical theory. Explanation by simplification, on the other hand, is quite in the spirit of modern mathematics. It is not ultimate explanation, to be sure, but we realize that to be as impossible as ultimate proof.

Physics, then, is but applied mathematics. It differs enormously from mathematics as regards the actual activity of its followers, but it differs from mathematics, in logical structure, in only two regards. Certain elements of the theory are identified with measurable entities, and the theory thus becomes one which may, on the test of experiment, prove to be false or true. There are two ways in which one can test the truth of a physical theory. One can subject its end conclusions to experimental verification; or one may test whether or not physical entities exist which actually satisfy the relations assumed as postulates in the mathematical theory. If the latter test can be made and if it succeed, then the whole mathematical theory obviously becomes, at one stroke, a true physical theory. If only the more remote theorems of the theory can be tested experimentally, then the situation is less definite. One can not, in general, then claim that the postulates are necessarily "true" in a physical sense. In fact, the situation may be even more vague than this. The identification with measurable entities may not refer to all or any of the primitive elements of the theory, but rather to constructs occurring in the development of the theory, formed from these primitive elements. The end theorems of the theory may then be true without our being able to give any physical interpretation whatsoever to the primitive elements themselves. This seems to be

the actual structure of important modern physical theories. One can appreciate the new tendency if he compares the atomic theories of ten or fifteen years ago with present atomic theories. The familiar theory developed largely by Rutherford and Bohr described the motions and interactions of a nucleus sun and various planetary electrons. One had a definite picture of an atom, and believed that his model exhibited so satisfactory and detailed a correlation with experiment that one was justified in concluding that atoms were actually constructed after the pattern of the model. The modern quantum theory of the atom, however, is quite a different sort of affair. It starts, as formulated by Dirac, with abstract variables called "states" and "observables" which satisfy certain assumed postulates. An algebra of these variables is then developed, and, near the end of the work, a decoding process is introduced so that equations in these abstract variables may be formally translated into statements concerning the result of certain experimental measurements. To ask, in this theory, what the inside of an atom looks like or to ask concerning the path of an electron inside an atom are meaningless and silly questions. One has simply constructed a formal mathematical theory, which, at some stage in its development, is decoded into physical language and is thus made susceptible of experimental test. The important matter, from our present point of view, is that this decoding does not take place at the beginning of the theory. It is thus not possible to test directly whether or not the postulates are experimentally satisfied; nor is it possible to give physical meaning to the abstract variables with which the theory began.

If one is, then, to construct a physical theory by constructing a mathematical theory and adding to it a decoding or interpretative appendix, and if this physical interpretation is to occur so far along in the theory that one can not ask, "Are the postulates physically true?" nor can he even ask, "What is the physical interpretation of the terms in which the postulates are phrased?"—if this be the plan of a modern physical theory, then where, one may ask, is one to get the postulates with which one has to begin? In the earlier stages of physics one felt himself guided, in the choice of his original assumptions, by his previous experience in the laboratory and by his so-called physical intuition, just as the early mathematicians felt themselves guided by their judgments of the self-evident. The modern physicist has no such hold on so-called reality. He has grown to feel that nature is a very shy nymph who conceals from us mortals her personal charms, only allowing us the privilege of describing some of her more remote manifestations. Mr. J. W. N. Sullivan, in his charming essay called "Gallio, or The Tyranny of Science," says: "All that depends on the *structure* of reality belongs to physics, including other universes than ours. All that depends upon the *substance* of reality forever lies outside physics."

The upshot of the matter, then, is that modern physicists live in a world of their own making; and in the making of it they have been so little guided by the past that, almost as completely as is the case with pure mathematicians, it has been their creative imaginative faculties which have been most called into play. Modern science, like modern mathematics, is no materialistic Juggernaut; it is a creative and imaginative art.

If one is himself convinced that mathematics and physics are imaginative arts, he may finally wish to ask whether or not they have been so recognized by other artists. The answer comes, in beautiful form, from a sonnet of Edna St. Vincent Millay. She is speaking of geometry, a subject which,

fifty years ago, we would unhesitatingly have called mathematics, but which we now recognize to be mathematics only providing one is talking about so-called points, lines, planes, etc., but which we recognize to be physics if one is talking about points made by pencils, lines drawn on paper, etc. Indeed, we not only recognize geometry to be physics, but we have learned from Einstein that it is one of the most significant branches of physics. It is satisfying, then, to have the answer of the poetess refer to a subject which so admirably illustrates the arguments made above, and to have her poem, in its every detail, so completely in accord with the modern philosophy of mathematics and science:

Euclid alone has looked on Beauty bare.
Let all who prate of Beauty hold their peace,
And lay them prone upon the earth and cease
To ponder on themselves, the while they stare
At nothing, intricately drawn nowhere
In shapes of shifting lineage; let geese
Gabble and hiss, but heroes seek release
From dusty bondage into luminous air.

O blinding hour, O holy, terrible day,
When first the shaft into his vision shone
Of light anatomized! Euclid alone
Has looked on Beauty bare. Fortunate they
Who, though once only and then but far away,
Have heard her massive sandal set on stone.

HOW THE LAUGHING GULL, THE FEATHERED BUCCANEER OF FLORIDA WATERS, GETS ITS DINNER

By Dr. E. W. GUDGER

BIBLIOGRAPHER AND ASSOCIATE IN ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

SWINGING southwest and west from the tip of the mainland of the Florida peninsula at Jewfish Creek, the great submarine Florida plateau, with its bird-populated keys and its fish-inhabited reefs, ends abruptly in the archipelago of the Tortugas. In the 107 miles of this distance from Jewfish Station on Key Largo to Key West, the keys are so close together and the intervening water so shallow that the Florida East Coast Railroad has built an extension over and between them to that city. But in the seventy miles from Key West to Loggerhead Key, the breaks are too wide and the water too deep for man to bridge. And on these outer keys the little-disturbed wild life remains almost as it was sixty years ago.

The Tortugas (Islands of the Turtles) consist of seven small, treeless islets, composed of coral rock and sand heaped up by waves and winds, which with their surrounding reefs enclose a lagoon of forty or fifty square miles area, shallow for the most part but with intersecting channels of deep water. They are the last far-flung remnant of the Florida Keys, the Ultima Thule, the "jumping-off place," the land's end of the Florida Reef, and beyond is nothing but "blue water" until one reaches the Mexican coast one thousand miles away.

Here in this absolutely isolated spot it was my good fortune to spend four summers at the Marine Biological Laboratory of the Carnegie Institution of Washington studying fishes. The laboratory is located on Loggerhead Key, so called because the loggerhead turtles used formerly to "haul out" there in great numbers to lay their eggs in the sand. Two miles east of Loggerhead is Garden Key, covered over with the ruins of an old brick-built stronghold, Fort Jefferson, so named for Jefferson Davis, under whom as secretary of war it was begun in 1847. South of Garden Key is Bird Key, a bird sanctuary with a guardian warden during the breeding season when it is literally covered with birds, their eggs and young.

Sea birds abound here and may be seen perched on every available resting place, on buoys, channel stakes, old wrecks—everywhere that they can secure a footing. But although these are the "Turtle Islands" (they were named Tortugas in 1521) I have never witnessed the interesting sight which Zane Grey tells us in one of his books that he saw in the Bay of Tehuantepec. He says that "About noon, when the sun was hottest, we began to see birds standing on the backs of turtles [sleeping at the surface of the water]. . . . Terns and gulls and one booby made of these oval green backs a resting place." However, I can go Dr. William Beebe one better, although he saw in his Islands of the Tortoises (the Galapagos) "a noddy tern alight on the head of a pelican, without eliciting any protest."

Florida, including the Tortugas, belonged to Spain until it was finally ceded to the United States in 1821. Up to that time and even later piracy was rife and buccaneering very much the fashion in Gulf-Caribbean waters. The Tortugas, commanding the straits of

—*After Holder, 1892*

FIG. 1. THE LAUGHING GULL HAVING ALIGHTED ON THE HEAD OF THE PELICAN AWAITS HIS CHANCE TO STEAL THE FISH FROM THE LATTER'S BEAK.

Florida, the entrance to or if you so please the exit from the Gulf of Mexico, was an admirable location for a lair of the buccaneers. Moreover, having three deep water channels penetrating the lagoon, it could not be successfully blockaded. Hence for a long time it was a most desirable rendezvous for the pirates of the Gulf. And later still it was headquarters for the wreckers who plied their nefarious trade along the western keys. And about the same time it was a transshipping point for Mexican and Central American gun-runners, as J. Fenimore Cooper has written in his novel "Jack Tier." Now although buccaneers of the genus *Homo* have long since departed, those of the genus *Larus* still abound, and ply *their* nefarious trade brazenly and unchecked—as will now be shown.

In front of the sally-port of deserted Fort Jefferson on Garden Key, and separated from it by a deep channel, is Long Key, composed of white coral sand. This extends northeast and curves east to where a shallow channel nearly dry at low tide separates it from Bush Key, now composed only of dead coral heaped up by the waves, which in turn swings southeast and south. On these keys lived and nested many laughing or black-headed gulls (*Larus atricilla*), and in the shallow lagoon partly enclosed by these keys, some brown pelicans (*Pelecanus fuscus*) generally could be seen floating idly on the surface with their bills resting on their breasts, their eyes closed and their long necks curved until their heads rested on their backs, or sedately pursuing their prosaic task of catching fish.

Here one day toward the close of the season of 1914, while watching the sharks in the lagoon, I saw a laughing gull light squarely and securely on the head of a somnolent pelican. The pelican, thus rudely awakened, automatically arose in lumbering flight, the gull hovering closely around him, but seeing beneath him a fish swimming near the surface he dove down and seized it with his hooked bill. Floating on the surface, the pelican lifted his head and stretched out its neck and bill to get the fish in

—*After Holder, 1892*

FIG. 2. WHEN THE PELICAN LIFTS HIS BEAK AND STRAIGHTENS HIS NECK TO SWALLOW THE FISH, THE GULL ADROITLY SEIZES THE PREY AND FLIES AWAY WITH DERISIVE HA HA'S.

—*Slightly modified from Ealand, 1921*

FIG. 3. LAUGHING GULLS TEASING A BROWN PELICAN AND ALIGHTING ON ITS HEAD TO ROB IT OF THE LITTLE FISHES WITH WHICH ITS POUCH IS FILLED. FIGURE DRAWN TO ILLUSTRATE THE SCENE IN KEY WEST HARBOR SEEN BY AUDUBON IN 1832.

position to swallow head first—to prevent any casualties from its spiny fins catching in his throat—when the saucy gull again alighted on his head, reached around, deftly seized the fish and flew away with it amid a chorus of derisive ha-ha's from its fellows. This interesting thing happened several times that afternoon while I, immensely pleased, thought that I had witnessed a thing in bird behavior absolutely unknown to scientific men. But sad to say, I had no camera to secure a record of it, and unfortunately I never saw it again in the short time before leaving Tortugas.

But alas! "There is no new thing under the sun," as Ecclesiastes the Preacher well says. For, a few weeks later, when on my way north, I visited friends at Cocoanut Grove, Florida (near Miami), who lent me a copy of Dr. Charles F. Holder's charming book "Along the Florida Reef."[1] From 1859 to 1869 Holder's father, Dr. J. B. Holder (later a curator in the American Museum), resided at Fort Jefferson, while engaged in the study of the growth of corals. For nearly two years he also served as surgeon to the troops there. Charles F. Holder spent most of these ten years here, and accumulated a vast lore of sea things which he later put into many interesting books. Among other things, he witnessed an identical performance by the birds in this identical lagoon.

Holder first described this interesting incident in one of a series of delightful papers bearing the general title "Among the Florida Keys" in *St. Nicholas Magazine* for 1889.[2] These articles were later expanded into the book above named, and from it will now be set forth his own vivid account of what he saw illustrated by copies of his own pictures:

> The old birds [pelicans] were hard at work, diving for fish in the lagoon. The boys watched one, which was near them, with no little curiosity. It would flutter an instant over its prey, then plunge down and with open, dip-net bill resting on the water, would adjust the catch in its capacious pouch beneath. In one of these expeditions a gull, with trained and eager eye, hovering near, settled down upon the pelican's broad head, and as the fish was tossed about, preparatory to swallowing it, the thievish gull adroitly snapped it up and sailed away with a derisive "Ha, ha!" while the pelican, as if accustomed to this sort of pocket-picking, flapped heavily up again to renew its search for food.

Years later I learned that Holder in his turn was not the first to see this interesting method by which the laughing gull procures its dinner. That great naturalist, John James Audubon, saw the same thing in 1832 and describes it in his "Birds of America." In his account of the brown pelican,[3] Audubon says of it that "it acts unwittingly as a sort of purveyor to the Gulls," and that when it has caught a number of small fishes and is endeavoring to swallow them "the Gull at that instant alights on the bill of the Pelican, or on its head, and seizes the fry" which the pelican thinks he has safely imprisoned for his dinner. In his account of the laughing gull[4] he relates that on May 10, 1832, the revenue cutter *Marion* furled her sails in the harbor at Key West and that "the Gulls laughed whilst our anchors were swiftly descending towards the marvelous productions of the deep." He then goes on:

> They [the laughing gulls] were all busily engaged on wing, hovering here and there around the Brown Pelicans, intent on watching their plunges into the water, and all clamorously teasing their best benefactors. As with broadly extended pouch and lower mandible, the Pelican went down headlong, so gracefully followed the gay rosy-breasted Gull, which, on the brown bird's emerging, alighted nimbly on its very head, and with a gentle stoop instantly snatched

[1] New York, 1892.

[2] On page 781, Vol. 16, are this account and figures.

[3] "Birds of America," Vol. 7: 35. New York and Philadelphia, 1844.

[4] P. 141.

from the mouth of its purveyor the glittering fry that moment entrapped! . . . The sight of these manoeuvres rendered me almost frantic with delight. At times several Gulls would attempt to alight on the head of the same Pelican, but finding this impossible, they would at once sustain themselves around it, and snatch every morsel that escaped from the pouch of the great bird. So very dexterous were some of the Gulls at this sport, that I have actually seen them catch a little fish as it leaped from the yet partially open bill of the Pelican.

The accompanying figure, which very accurately portrays the scene, is copied from E. A. Ealand's "Animal Ingenuity of To-day,"[5] in which book he quotes the incident without adding anything to it. On looking at the figure and visualizing the scene, one can readily understand that Audubon was "frantic with delight" when he first saw this charming performance. That was certainly my feeling that day in June, 1914, when I in my turn saw "How the Laughing Gull Gets its Dinner."

[5] London, 1921.

THE USEFULNESS OF THE USELESS

By Dr. CHAS. N. GOULD

DIRECTOR, OKLAHOMA GEOLOGICAL SURVEY

LAST week I found among the routine correspondence on my desk a letter from a friend inquiring if I knew of a young man whom he might employ as an assistant. This friend is the geologist for a small oil company operating in Oklahoma, and is engaged in general scouting for new oil fields. Among his other duties, he watches the various oil wells that are being drilled by his own company as well as by other companies in the region in which his company operates.

One sentence in his letter of inquiry struck me very forcibly. The young man whom he wished to employ must be able to identify microfossils, and must also be able to make heavy-mineral determinations—this in addition to general training in structural and stratigraphical geology and in the use of the plane table and telescopic alidade. He should also be versed in subsurface methods of correlation and know something of geophysical instruments.

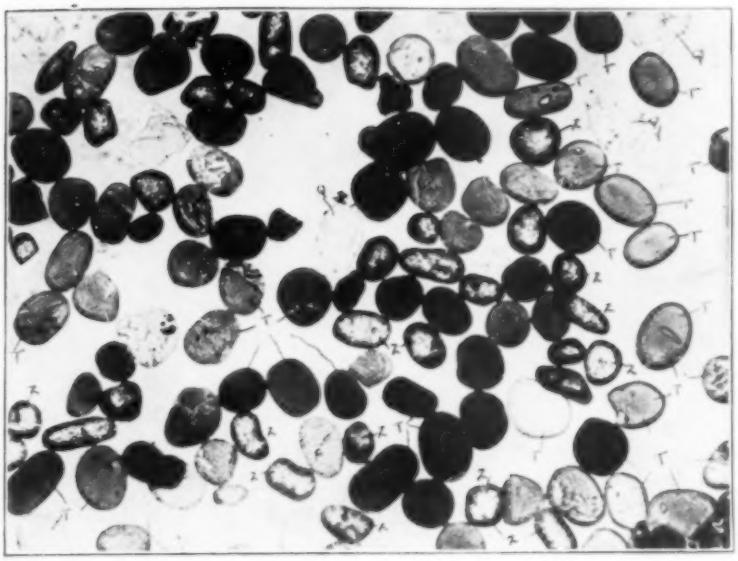
PITY THE POOR STUDENT

When one comes to think of it this is a rather large order for a young chap just out of college. But it is not an unusual demand. The young geologist who to-day graduates from any one of a score of schools of geology or petroleum engineering in the United States is supposed to have at his fingers' ends these various requirements. He must have sufficient training in engineering to use the alidade and plane table, and must be well enough acquainted with physics and higher mathematics to have at least an elementary knowledge of the magnetometer, torsion balance, seismograph and other geophysical instruments. He must know not only megascopic fossils, but microscopic forms as well, and this knowledge naturally presupposes some knowledge of zoology. He must understand the principles of stratigraphy and sedimentation, and have fairly good training in mineralogy and in igneous petrography.

THE PLACE OF IGNEOUS PETROGRAPHY

Ten years ago who would have thought that these somewhat diverse and more or less abstruse sciences would to-day have a practical application in this work-a-day world? Who could have imagined that such things as igneous petrography or the identification of sand grains under the microscope would be of commercial importance in one of the great industries of the world? Who could have had the temerity to suspect that the identification of tiny fossils under the microscope in the laboratory of the geologist would determine the matter of the expenditure of tens of thousands or hundreds of thousands of dollars in the drilling of deep wells in the search for oil? Yet these things are to-day part of the ordinary routine of many oil companies.

Ten years ago the men in the United States who were trained in petrography were rather few. The subject was supposed to have no particular commercial importance, and for that reason relatively few men concerned themselves with it. It was then one of the so-called "cultural" studies, something like Greek or psychology or higher mathematics. Students who came to school and followed the ordinary custom of browsing around among the different departments sometimes happened to drop into geol-



—*Oklahoma Geological Survey*

HEAVY MINERALS IN SIMPSON SANDSTONE, WILCOX SAND

FROM THE ARBUCKLE MOUNTAINS, CONTAINING ABOUT 75 PER CENT. TOURMALINE AND 25 PER CENT. ZIRCON. THE CRYSTALS ARE LABELED T AND Z RESPECTIVELY.

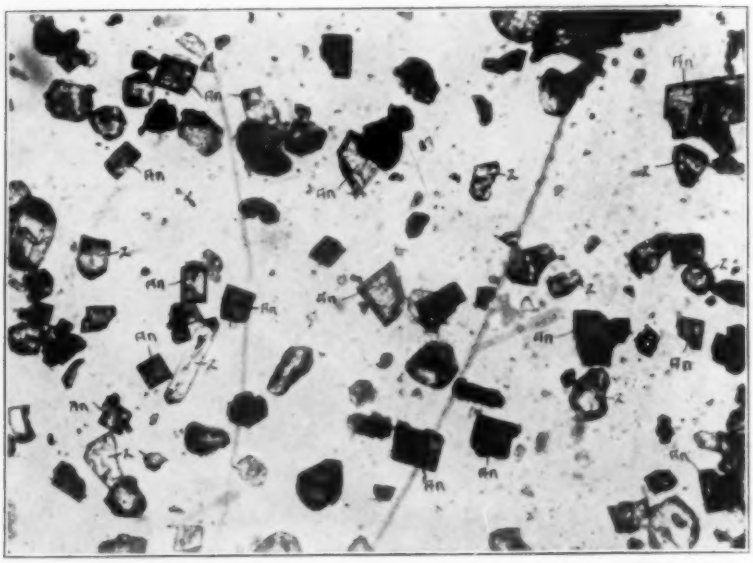
ogy, and in the natural course of events took mineralogy, and later, with no particular reason for so doing, wandered into classes in petrography. Very few of them, relatively speaking, really became interested in the subject, but the great majority took it just as they took all other subjects, because it was scheduled in the catalog and would produce credit which counted toward graduation and a diploma. Something like the medicine which the old-time doctor used to give, which was labeled, "Good for what ails you. Shake well before using."

But the possibility of putting to any practical use the information gained by studying sand grains and rocks under the microscope was far from the thoughts of those who studied these subjects. A few really enjoyed the science and became teachers in colleges, and so passed the science on, inflicting it on other students. A few practical men engaged in mining engineering or kindred professions occasionally used the subject. Some of these men, both engineers and college professors, wrote for technical journals and magazines. But no one would for a moment have classified the subject of igneous petrography among the popular, or so-called useful, sciences. It was not a "bread-and-butter" subject.

But all this has been changed, and almost over night. There is to-day a very urgent need for more students trained in petrography. And this need has burst upon us very suddenly. It was only a few years ago that the men connected with the scientific departments of the larger oil companies began to use heavy-mineral determinations in the correlation of deep well logs. These men found that certain beds of sandstone, especially those that were oil-producing under favorable structural conditions, possessed a rather definite mineral content.

HOW TO DETERMINE AN OIL SAND

If the drill in pounding its way downward encountered at a depth of 5,000 or



—*Oklahoma Geological Survey*

HEAVY MINERALS IN SIMPSON SANDSTONE, WILCOX SAND

FROM THE ARBUCKLE MOUNTAINS, CONTAINING ABOUT 85 PER CENT. ZIRCON AND 10 PER CENT. ANATASE AND SMALL AMOUNTS OF OTHER MINERALS.

6,000 feet a certain ledge of sandstone which did not contain oil, it was often of extreme importance to be able to tell whether or not this particular sandstone was the same as the one which, in another well of similar depth a few miles away, contained large amounts of oil. If this was the same ledge as the one which contained oil in the producing well, it would probably be useless to spend more money to drill deeper. If, however, the sands were not the same, and if the one just encountered lay at a higher level than the producing horizon, it would be the part of wisdom to drill deeper. The well had already cost a large amount of money, perhaps $75,000, possibly $100,000. It then became a very vital problem to determine by any known method whether or not the sand at the bottom of the hole was the one which in other areas produced oil, or whether it was some other sand.

HEAVY-MINERAL DETERMINATION

The chief way, and in many cases the only way yet discovered, in which this matter can be determined is by the microscopic examination of the sand grains. Experience has shown that certain sandstones contain rather definite proportions of certain minerals. Some of these minerals are easy to detect, others are not. The so-called heavy minerals, such as tourmaline, zircon, rutile, and the minerals composed of iron such as magnetite, hematite and pyrite, are usually easy to distinguish, and it is these that often form the basis for comparison and determination. It is no unusual occurrence, after a certain ledge of sandstone has been encountered, for drilling operations to stop, machinery to stand idle and workmen to loaf on the job while a sand sample from the bottom of a 5,000-foot well is sent hundreds of miles to the laboratory where the petrographer makes his tests. The question as to whether or not another $10,000 or $20,000 shall be spent in the deep hole, in addition to the $75,000 or $100,000 already expended, frequently rests upon the determination of the

particular type of sand grains under the microscope.

The Geologist's Clock

And so with the studies of microfossils. Fossils are the geologist's clock, the method by which he determines geologic time. Studies by many men in many lands for the last hundred years have shown that no two formations contain identically the same fossils. In the older stratified rocks, those of early Paleozoic age, certain rather primitive forms occur. As one comes higher and higher in the geologic section, the type of fossils changes, and there is shown a gradual, slow, but very determinable development of fossil forms from the older to the younger rocks.

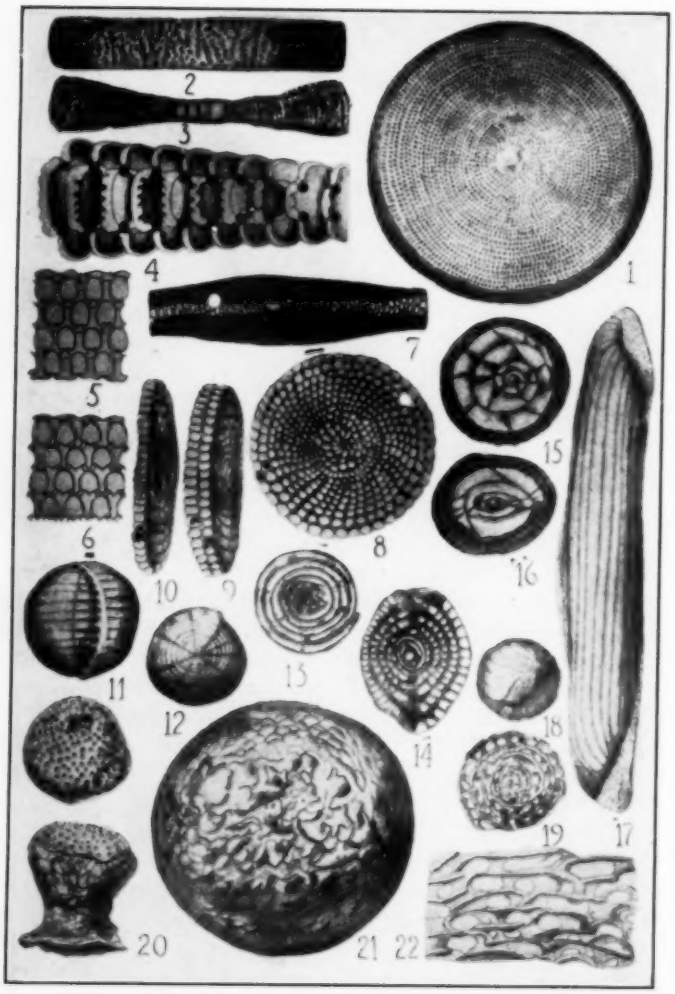
This story is told of James Hall, the veteran state geologist of New York many years ago. Dr. Hall stated that he was willing for any one to blindfold him, take him to any part of the state, turn him loose and permit him to find a fossil, claiming to be able to tell, if not the exact county, at least the general part of the state in which he was located. So with the trained paleontologist of to-day. You may throw into a tray fifty fossils selected at random from different geological horizons and from all parts of the world, and this paleontologist will be able to pick out the particular fossils from the various geological ages. True he probably will not be able to tell whether a certain Ordovician fossil came from Wales, from New York or from Missouri, or whether a certain Pennsylvanian fossil came from the coal fields of England, the coal fields of Pennsylvania or the coal fields of Oklahoma, but he can tell without question that the one fossil is Ordovician and the other Pennsylvanian.

Geologists have found this underlying principle of much value in identifying formations. The drill in penetrating downward passes through various ledges of rock, sometimes shale, sometimes limestone, sometimes sandstone. Many of these ledges, particularly the limestones and shales, contain large numbers of fossils. The fossils from the ledge at the bottom of the well will never be quite the same as those found in formations at the top of the well. This is especially true when the well passes through rocks of several different geological ages. So the oil man has found that the geologist by identifying these fossils is often able to determine the geological formation in which the drill is working, and, as in the case of heavy minerals, he will often be able to tell whether or not it is worth while to penetrate deeper in searching for a particular oil sand.

Microfossils

The difficulty is that the drill in pounding its way downward breaks up, mashes and destroys most of the larger fossils. Such forms as trilobites, corals, shells and most other fossils large enough to be seen with the naked eye are often so broken and macerated that their fragments can not be determined. Occasionally a recognizable fragment will come out of a drill hole, and very rarely an almost complete fossil may be obtained which will give the geologist a clue, but as a general rule the larger or megascopic fossils are so broken as to be unreliable as a means of determination.

This fact has given a great impetus to the science of micropaleontology. It has been found that most shales and many limestones contain great numbers of very minute fossil forms, those that are often too small to be seen with the naked eye. At the same time, it has been discovered that these microforms are diagnostic, that is to say, they are valuable for the determination of different strata. These little fellows are the forms that are now being used by the paleontologist in determining the identity of deep-lying formations.

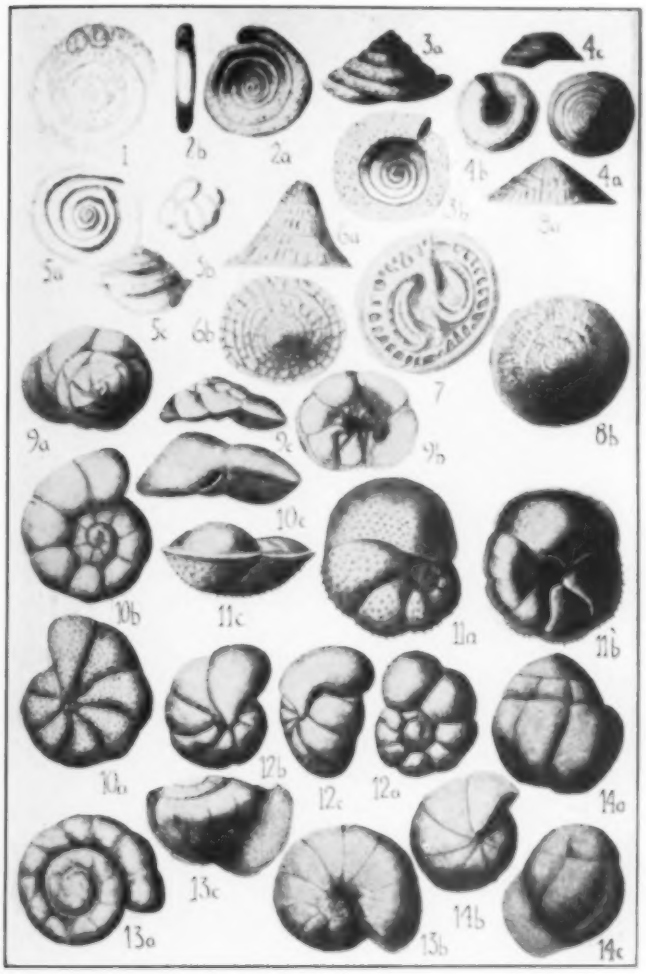


SOME MICROSCOPIC FOSSILS

THE PHOTOGRAPHS SHOW SEVERAL TYPES OF MINUTE FORMS OF LIFE, THE ILLUSTRATIONS BEING GREATLY ENLARGED. (THE TWO ILLUSTRATIONS ARE FROM "FORAMINIFERA, THEIR CLASSIFICATION AND ECONOMIC USE," BY JOSEPH A. CUSHMANN.)

Shales and fragments of limestones from the bottom of the well are sent to the laboratory, and this material is washed, sieved, dried and studied under the high-powered microscope, and the results obtained are used to determine the particular geological formation in which the drill is working. As in the case of heavy minerals, it often happens that operations at the well will be suspended for several days while the cuttings from the bottom of the hole are sent to the laboratory to give the micropaleontologist an opportunity to pass upon them.

Ten years ago there were perhaps not more than a half dozen men in the United States who gave any particular attention to micropaleontology. As in the case of igneous petrography, the subject had no commercial appeal. "There was no eating in it." The few



SOME MICROSCOPIC FOSSILS

men who studied microfossils were generally considered pedants or mild sorts of cranks, whose labors served no useful purpose. They were devotees of "pure" science, using the term "pure" to mean something which had no particular utilitarian purpose.

What Does the Oil Man Want?

To-day the condition is very different. When the oil man once found that the paleontologist by a study of these minute forms could actually aid him in "putting oil into the tank" he at once became an advocate of micropaleontology.

Not that the oil man knows what it is all about. Far otherwise. The ordinary petroleum executive has no love for science as such, and has no burning desire to promote scientific research. What he wants is to strike a gusher formation and get the oil out of the ground and into his own tanks before the other fellow has a chance at it. But he has learned that the micropaleontologist as well as the petrographer in his

determinations of heavy minerals has something which will often help him to put oil into the tank. Therefore, for that reason and for no other, he is strong for scientific work, which he by no means understands, as long as it can help find the oil.

"Pure" Science on the Boom

All of this means that these two sciences, petrography and micropaleontology, are now "on the boom," in many universities. Young men and women have learned where these subjects are well taught and to-day the men who teach them well are overwhelmed with students. In some of our American universities the departments of geology and paleontology are to-day overcrowded, and, on account of inadequate teaching personnel and insufficient laboratory facilities, are turning away students who desire to enter.

In the case of micropaleontology, until within the last few months there never has been a suitable text-book on the subject, and to-day the science is in an unformed state because the various workers have not yet been able to record in type and in figures the many new forms that are being discovered. A new publication, the *Journal of Paleontology*, and various paleontological reports published by geological surveys and magazines are now busy recording the many new genera and species that are being discovered by the workers in this field. During the next decade the science should have opportunity to crystallize, and the nomenclature to become fairly well established.

Making Useful the Useless

One might unduly enlarge this article to include other of the various new methods being used to discover supplies of petroleum, but these two examples of petrography and micropaleontology must suffice. The use of the telescopic alidade and plane table for making contour maps might well be discussed. Or something might be added regarding the training of young men in the use of geophysical methods or the work now going forward in various states for working out geothermal gradients by taking deep-well temperatures. The ceramics method of burning clays and observing their colloidal qualities and the analyses of subsurface brines might be described. All these methods and others not known a decade ago are now being used in the petroleum industry. Other methods are only to-day peeping over the horizon. Just how far they will be found to be practical no one knows. However, those of us who have watched the development of the industry for a quarter of a century believe that as the years come and go these and other new methods will continue to be developed and improvements made in the search for and recovery of oil, and that many things now considered useless by the man on the street will be found to be useful.

SIR HUMPHRY DAVY

By Professor BENJAMIN HARROW

COLLEGE OF THE CITY OF NEW YORK

THE centenary of the death of Sir Humphry Davy has recently been observed. At this time it might not be amiss to recount some of the activities of one of England's greatest chemists.

Davy's fame rests upon a number of outstanding contributions: the physiological properties of laughing gas; the application of electricity to chemistry, with the consequent isolation of the alkali metals; a more exact knowledge of the halogens and the halogen acids, and, standing quite apart from any of his researches, the safety lamp. Davy was a brilliant experimenter, bold and quick in execution, somewhat hasty in his conclusions and not very much of a speculator. We owe no far-reaching theory to his genius, but we are indebted to him for opening up a new branch of chemistry. For this electrochemistry which he was the first to cultivate has

since his day broadened sufficiently so that we have, on the one hand, theories of chemical action intimately related to electricity, and, on the other hand, many applications of electricity in the chemical industries.

Davy's talents remind one of another countryman of his, Sir William Ramsay. Both were geniuses in the laboratory; both worked rapidly; both were not always painstaking, but rather quick in execution and sometimes hasty in deduction. Compared with their brilliant qualities as experimentalists, the theoretical background of both was weak. Neither is the author of any profound theory. Both belong to the "dashing" variety of scientist—to what Ostwald calls the "romantic" type.

Davy was born in Penzance, England, in 1778. Like many chemists of English stock, his early training seems to have been anything but systematic. At a somewhat later age he was apprenticed to a local apothecary and here he picked up much miscellaneous information. But what, of course, really counted was that the gods had endowed Davy with what we call genius; and the genius was of the chemical variety; and the apothecary's "shop" was where this genius could find some play. He read Lavoisier's "Elementary Chemistry" and he began experimenting with the primitive tools available to him. Then came the opportunity which allowed this genius to blossom. In Bristol there was a "Pneumatic Institute" which had for its object the investigation of the medicinal effects of various "gases." "Gases" were fashionable ever since Priestley and others had discovered them; and people began to wonder whether the physiological effects of such gases might not be of some value; hence arose the Bristol Institute. But the more important event was that Davy, at the age of twenty, was offered a position in this institute.

Davy had scarcely established himself in Bristol when he began his experimental work on "gases." One of these, "diminished nitrous air," was first prepared by Berthollet in 1785 by heating ammonium nitrate; and now Davy investigated its properties. Among other things, he inhaled the gas and found that it was not only non-toxic but acted much like a stimulant, arousing pleasurable feelings. Southey, the poet, whose acquaintance he had made, also inhaled some of the gas, and he wrote: "When I took the bag from my mouth, I immediately laughed. The laugh was involuntary, but highly pleasurable, accompanied by a thrill all through me, and a tingling in my toes and fingers, a sensation perfectly new and delightful." Experiences such as Southey's suggested the name "laughing gas," though the chemists of our day call it "nitrous oxide." But Davy made the important observation that inhaling nitrous oxide deadens pain; and he described this property in connection with a bad toothache, the pain of which "almost diminished after the first four or five inspirations." We must also thank Davy for a very careful chemical analysis of nitrous oxide, which he accomplished by burning charcoal in the gas, measuring the nitrogen that was left after combustion and calculating the oxygen from the carbon dioxide produced. If our system of atomic weights and our modern nomenclature were used, Davy's analysis would lead to the formula N_2O for nitrous oxide; which is, as a matter of fact, the accepted formula for the gas.

Davy's work attracted the attention of Count Rumford, who had recently laid aside his own notable researches in physics to found the Royal Institution in London. Rumford offered the post of chemical lecturer to Davy at the new institution. Davy accepted. Within twelve years Davy became the most celebrated chemist in England, and the Royal Institution became known wherever science flourished. It is this same institution that Faraday, Dewar

and Bragg have worked since the time of Davy.

It was in 1790 that Volta produced an electric current by means of the voltaic pile, and it was some eleven years later that Nicholson and Carlisle decomposed water by means of the electric current. Davy was very much impressed with the possibilities of the electric current. He had an intuition that the application of electricity to chemistry would yield valuable information as to the chemical make-up of bodies. With this in mind, he built himself a battery "containing 24 plates of copper and zinc 12 inches square, 100 plates of 6 inches, and 150 of 4 inches square, charged with solutions of alum and nitric acid"; and he immediately attacked the problem of the nature of the caustic alkalis.

In a very general way, the alkalis were looked upon as elementary substances, though there were some vague questionings on this point. Davy had his doubts, together with others, and he hoped that his battery might be of some service in settling the question. He first passed the current through a solution of potash; in this experiment he merely succeeded in decomposing the water without affecting the potash. He next used fused potash and was more successful, particularly when he used the electricity as a heating agent (to fuse the potash) as well as for the purposes of decomposition.

A small piece of pure potash was placed upon an insulated disk of platina, connected with the negative side of the battery, and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The potash began to fuse at both its points of electrization. There was a violent effervescence at the upper surface; at the lower there was no liberation of elastic fluid; but small globules having a high metallic luster, and being precisely similar in visible characters to quicksilver, appeared, some of which burnt with explosion and bright flame, as soon as they were formed, and others remained, and were merely tarnished, and finally covered by a white film which formed on their surfaces."[1]

Not only did Davy, in this manner, show that caustic potash was a compound, and that an element, potassium, could be isolated from it, but he showed that what was true of caustic potash was likewise true of caustic soda; that the latter, like the former, was a compound, and that by means of the electric current an element, sodium, could be isolated from it. This work was, in turn, followed by an exhaustive examination of the alkaline earths and by the ultimate isolation of the elements barium, calcium and strontium.

Davy was now in the full bloom of intellectual vigor. No sooner was he through with the alkalies and the alkaline earths than he turned his attention to another puzzling problem of the times: the elementary nature of chlorine. Ever since Scheele's discovery of the gas there had been doubts as to whether chlorine was an element or a compound, and the weight of opinion seems to have been in favor of regarding the gas as a compound. Berthollet, for example, regarded chlorine as an oxygen compound; and even Gay-Lüssac looked upon the gas as an oxide of an imaginary metal. Davy's powerful voltaic battery and the success he had had in using it to determine the elementary nature of substances suggested to him that the battery might be applied to elucidating the nature of chlorine. All attempts to decompose chlorine failed. Even when acted upon by charcoal heated to whiteness by the voltaic battery, no decomposition took place, suggesting that the persistent belief that chlorine contained oxygen had no foundation in fact. After many experi-

[1] For this quotation, as well as for a number of others, I have to thank Professor T. M. Lowry, who, in his book "Historical Introduction to Chemistry" (Macmillan), has made an exhaustive study of original material.

ments Davy was led to the conclusion that

> the body improperly called oxymuriatic acid has not yet been decompounded; it is a peculiar substance, elementary as far as our knowledge goes, and analogous in many of its properties to oxygen gas. It has been judged most proper to suggest a name founded upon one of its obvious and characteristic properties—its color—and to call it "chlorine."

Davy also busied himself with two other halogens: iodone and fluorine. Iodine was discovered by Courtois in 1811 and its properties were very carefully investigated by Gay-Lussac and Davy. Again making use of his battery, Davy assured himself that iodine could not be decomposed. "In its specific gravity, luster and color, it resembles the metals; but in all its chemical agencies it is more analogous to oxygen and chlorine." He, indeed, proposed the name "iodine" for it. While fluorine was not isolated until much later—in 1886, by Moissan—Davy did recognize that both fluorspar and hydrofluoric acid contained such an element, and he even attempted to isolate it by passing an electric current through hydrofluoric acid—a modification of which method was successfully used by Moissan.

Davy was now—in 1812, when thirty-four years old—at the very height of his fame. He was easily the most famous, and, incidentally, the most popular chemist in England; and, with the exception of Berzelius, probably the most talked about chemist in all Europe. In this year he was knighted and within three days of his knighthood he married a rich widow. From now on Davy becomes Sir Humphry Davy, rich and prominent socially; and from now on he becomes less and less active, scientifically. He undertakes a tour of Europe on the grand scale. He meets Gay-Lussac, Berthollet, Cuvier, Humboldt and Volta. He is accompanied by a young man who sometimes acts as his secretary and sometimes is made to do the work of valet, particularly when Lady Davy is around. This young man had received an appointment as assistant to Davy at the Royal Institution, and his name is Michael Faraday. Davy returns to England, delivers popular lectures at the Royal Institution, works a little in the laboratory, but not so very much, writes a little, but not so very much, meets all the lords and ladies of the realm and all the literary gentlemen of the kingdom, and eventually succeeds Joseph Banks as president of the Royal Society. But in the meantime he has invented one thing for which the miner will forever bless him—the Davy safety lamp. And in the meantime his health, never particularly robust, has taken a turn for the worst. He takes frequent trips to Europe, usually alone, because, it would seem, his wife brought him money rather than happiness. In 1829, in the course of one of these European trips undertaken primarily to improve his health, he arrives in Geneva, and never leaves the place again. There Davy died in the same year, and there he was buried.

EXTENT OF PERSONAL VOCABULARIES AND CULTURAL CONTROL

By Professor J. M. GILLETTE
UNIVERSITY OF NORTH DAKOTA

In view of the fact that language is so fundamental in human affairs, it provokes much less attention than might be anticipated. We are surrounded by a medium of culture of which language is the vehicle as fish are surrounded by air or land animals by the atmosphere, and yet the vast majority of human beings are quite as unaware of this contiguous stratum as animals are of that which impinges upon them. After a type of animal developed which had sense, mentality enough to turn round upon its environment, inspect it, draw inferences about it, great interest was taken in its study and important results therefrom ensued.

Just how language sprang into existence no one knows exactly, but there is an abundance of theories concerning it. There is considerable agreement that close to the beginning of human life pantomime played a large rôle and was the chief mode of passing on information. Hunters, warriors and adventurers came back full of their exploits and had to give expression to them in some way. To-day a man turns loose a barrage of words and relieves himself of the tension. Then, in default of words, he had to gesticulate, imitate his former actions, represent by attitudes and postures, describe situations by means of graphic movements. It is supposed that in the excitement of this portrayal grunts and cries which may have accompanied the original activities were expressed. Probably a part of the mimicry of the situation one was trying to depict consisted of the imitation of sounds by vocal expressions. Ultimately the various kinds of sounds came to have a somewhat definite meaning and could be used apart from pantomime as signs of meaning. And after ideas could be communicated by sounds and descriptions given, these utterances would undergo a development. They would differentiate, grow in number, become more definite and so come to be an oral tongue or language. With the evolution of human society through savagery, barbarism and civilization words multiplied, syntax and grammar emerged, writing and printing came to crystallize forms of speech and embalm them in human memory. Travel and trade greatly augmented the number of terms and when science developed a still greater extension of words and terms took place.

Some one has given rise to a theory of language which is a reverberation of that early period of human life when physical effort was such a pronounced and vital part of carrying on communication. It centers on the idea that language is primarily oral with us, that it is vocal, made up of sounds produced by the manipulation of the vocal organs. We can not produce sounds without making an effort to work our organs of speech in just the right way. As a consequence of the effort we make to talk, we have a lively memory of the attitudes, adjustments, and movements of the vocal organs we experience in talking. So it comes about that our memory of words is largely a memory of the physical adjustments and efforts accompanying talking and that when we are listening to some one talking we are trying all the time to reproduce the muscular adjustments of vocal organs necessary to produce the words we hear. And beyond

this, we are intently scanning the facial movements of the speaker and interpreting the muscular activities rather than the sounds registered in our ears.

Human beings are enveloped by a medium on which they are dependent for getting a living and adjusting themselves to others. This is culture or the cultural surplus. This culture is not the academic stuff, that infinitesimal portion of all extant knowledge which college boys and girls get during their few years sojourn in academic halls and are told represents the *sine qua non* of existence. It is the totality of all the ideas, inventions, plans, ways of doing things, customs, manners, codes, institutions, sciences, arts and whatever men's minds have brought into existence during the whole course of social evolution that have continued as a part of the social environment. This cultural surplus, beginning as a tiny trickle hundreds of thousands of years ago in the nascent society of eolithic man, becoming a sluggish brook among paleolithic men, a small river with neolithic men, has incremented more and more rapidly during later culture epochs and with torrential rapidity during the last century until to-day it envelops all civilized individuals in sea-like embrace. It ought to go without saying that what we call civilization is the culture surplus in its highest and most recent reaches and that were the culture increments of the last few centuries exscinded, higher civilization would be removed and such civilized life would be impossible.

Since this cultural surplus is so tremendously important, its control or use must be, of course, quite as important. In fact, it is by the employment of this culture in multitudes of ways that the work of the world gets done and the satisfactions and joys of life get accomplished. It is significant to realize that the avenue of access to this culture and the central, fundamental agency for its manipulation are unobtrusive and immaterial symbols: *words, vocabularies.* As culture grows, the number of words multiply accordingly. Mr. Karl Voghto estimates we have added 250,000 to our language since 1900.[1] The extent of our knowledge of words is a measure of the degree of our participation in the civilization of our age. The proof of this is of a very evident sort. If we think and know in symbols and only by the use of symbols, and if all the symbols we employ are words, either heard or seen, then we can have a knowledge of civilization and its accomplishments and undertakings only to the extent that we command a knowledge of the words and symbols by means of which the culture of our age is represented. Knowledge is the avenue to an understanding of the universe at large and of the human, social world with which we are most intimately associated. The child or the man who commands slight knowledge can have only the vaguest adumbration of the significance of either. Individual intelligences graduate upward from that point through larger and larger ranges of knowledge until the most gifted or cultured minds are reached—the minds which have a fairly adequate comprehension of our social and material worlds. But so far as we know, the only depositories our minds have for knowledge are words and symbols in the form of words.

The extent of one's vocabulary and the accuracy of the estimate made of it are both dependent upon the validity of the method employed in making the count. In consideration of this fact, it may be well to devote some attention to the question of methods.

Probably the oldest method is that which builds an opinion concerning the number of words a given person knows on counting the different words contained in his writings. Following this device, the students of Shakespeare's works have assigned a vocabulary of twenty-four thousand words to that

[1] *Popular Science Monthly*, January, 1929, page 48.

famous writer and those of Milton's works have found that the blind bard made use of seventeen thousand words. The numerous writers of the English Bible all together had to content themselves with handling only seven thousand two hundred words. But they lived in very primitive times for the most part and we could not use our standards of judgment on them. However, in the case of all publicists, it is to be remembered that the number of words they know is undoubtedly very much greater than they use in their writings; and that even the number of words they are capable of using is much more extensive than that appearing in their published works. It is interesting to note that some one has made a reckoning—how good a one it is impossible to say—that the late President Wilson knew over seventy-two thousand words. This estimate was made on the basis of the addresses and papers he produced during the war together with his earlier published works. And as we shall see later, the estimate of this large number is probably not only not exaggerated but is entirely too conservative. It is likely that Woodrow Wilson knew twice that number.

There have also been attempts, largely in the nature of pure guesses, to judge the extent of vocabularies of the rank and file of people. There are statements to the effect that Italian grand opera singers employ only about six hundred words, that the words used by many peasants number still fewer, being only three or four hundred, and that the vocabulary of persons above the average contains not more than three thousand or four thousand words. We must regard these as only rough and entirely inadequate guesses, for it is certain that primitive peoples who live in a much lower stage of culture than grand opera singers and peasants have considerably larger vocabularies.

A knowledge of the extent of vocabularies of primitive people throws a good deal of light on the subject under discussion. It furnishes a background on which to form a judgment concerning the capacities of peoples a great deal more advanced. If the daily spoken language of a savage folk is a matter of ten thousand words, what should be that of an enlightened people, and more especially that of those persons placed at the summit of the highest cultural attainment? We certainly should expect a developmental expansion of considerable moment.

There have been many dictionaries of primitive peoples compiled by missionaries and philologists. It is, therefore, quite within our power to make an estimate of the number of words in their lexicons. In these primitive vocabularies there are few or no dead and obsolete words, for, in nearly all cases, there was no written language and all the words the investigators collected were those which were in current use by the living men and women making up the groups. The chances, therefore, are that most of the adults of the group were in command of the bulk of the words constituting the vocabulary. According to Kroeber, the following are the number of words contained in the vocabularies of some primitive peoples: the Aztec Nahuatl, 27,000; the Central American Maya, 20,000; the Plains Dakota, 19,000; the African Zulu, 17,000; the Navaho of our Southwest, 11,000; the Klamath of our Northwest, 7,000. The range of culture of these groups is from upper barbarism to upper savagery. If the vocabulary of savages ranges from seven to nineteen thousand words and that of barbarians ranges still higher, what should be the extent of the vocabulary of the average civilized or enlightened Frenchman, German or Englishman? Undoubtedly it must be a multiple of the other.

There have been formulated in recent years certain standardized modes of estimating the number of words in any given person's vocabulary. One of these is the Terman test, which was devised in the

following fashion. From a dictionary containing eighteen thousand words, which are supposed to be the most common ones, was made up a list of one hundred words selected by taking the last word of every sixth column of the dictionary. This method of selection would prevent the operation of bias or prejudgment. Now the one who wants to test his vocabulary selects from the hundred words those which he can fairly well define. The resulting number is multiplied by 180. Did one know all the hundred words, his resulting vocabulary would be eighteen thousand. Did he only know one half of the hundred, his vocabulary would be nine thousand words. Upon applying the standard test to himself, the present writer found he has a vocabulary of 16,833 words. This is between one seventh and one eighth the number obtained by the method to be described later in this article.

According to the results obtained from the application of this test to a large number of persons, some average or general conclusions were obtained. A person eight years of age knows 3,600 words, one of ten knows 5,400, one of twelve knows 7,200, one of fourteen knows 9,000, the average adult knows 11,700, and the superior person knows 13,500. Using the test on college students, it was found that male students know the following number of words: Freshmen, 9,240; sophomores, 10,860; juniors, 13,040; seniors, 12,700. The vocabularies of female college students according to the same order of classes are: 8,860; 9,325; 10,130, and 10,700.

The general method of random or arbitrary sampling of the phenomena to be measured employed here in the selection of the basic list of one hundred words is scientifically correct. It is the method commonly used by scientific statisticians in their study of phenomena of every kind. A sample that is large enough and arbitrarily chosen is found to be an accurate representation of the whole realm of phenomena of which it is a part. Nevertheless, we are inclined to regard the Terman test as coming short of the results which such a test should attain. It probably understates the extent of the vocabularies of the persons to whom it is applied. It seems likely that the dictionary of eighteen thousand words is much too restricted and that consequently the multiple applied to the known words is not nearly large enough. Were the same method of sampling applied to an unabridged dictionary and a multiple applied which was adjusted to the size of the lexicon, the results would unquestionably be much more competent.

It should be clear by this time that one's estimated vocabulary is largely the outcome of the kind of method used in making the estimate and of the limitations imposed in the use of the method. Thus there are several bases for making an estimate which, if employed, would yield widely different results or sizes of vocabulary. There are: the ability to define words, the ability to use words irrespective of the ability to define them, knowing words for reading but not for speaking or writing purposes. The resulting vocabularies will vary in size in the order of the bases named.

The extent of the dictionary employed in formulating the standard or in making the test should be sufficiently extensive to provide for the inclusion of two very essential items: first, the technical vocabularies of professional persons, like doctors, lawyers, chemists, engineers; second, of business men, such as merchants, manufacturers and managers. A professional man or a technician has a knowledge of thousands of technical terms used in his calling in addition to the usual vocabulary of educated persons. As a sample of this I find that the manager of a Woolworth store in a city of twenty thousand inhabitants must know and have at his tongue's end the name of all the five thousand articles

contained in the store. Many of these articles are, of course, common articles which every one would know. But a well-equipped practitioner possesses a store of many thousands of technical scientific terms which are unknown to the laity. Second, it should include, also, the words built up on the foundation of certain basic words by a process of compounding through the use of prefixes and suffixes. Such words usually do not appear at the left margin in the columns of unabridged dictionaries, or at the foot of the column; consequently they are liable to escape inclusion in samples and so are not allowed for in multiples. Thus from the word *abolish* are built nine other words by the addition of suffixes. From the word *accent* are derived ten additional words. *Accept* gives rise to six and *access* to seventeen. Then by the use of prefixes twenty other words are added to the fifty-four so far derived from the four original words, altogether a total of seventy-four words. One gets the force of this method of multiplying words relatively to the size of one's vocabulary by supposing that the person in question knows five thousand words of the basic sort from which it is possible to build up other words. The average number of words built from the four words cited above was eighteen. Multiplying 5,000 by 18 yields a total of 90,000, the enlargement to the number of words the individual pretty certainly knows because he knows the foundational ones. This is a purely suppositious case, and instead of five thousand we might need to substitute four thousand, three thousand, or some other number. It certainly would not do to multiply one's entire vocabulary by such a multiple as 18 because much of the vocabulary is made of proper names, historical, geographical, and personal, which are not generally subject to taking on prefixes and suffixes.

It has been apparent to the writer of this article that there is a great surpise in store for any one who will make an elaborate and painstaking investigation of the extent of his own vocabulary, using as the basis of such test one of the great unabridged dictionaries of the English language. If he has hitherto looked up to Shakespeare as the consummate master of the language in all the phases and regarded himself as a mere pigmy in his knowledge of words when compared with the score and a quarter thousands Shakespeare is said to have made use of, his pride in himself will swell enormously after he has completed the self-investigation. Not that it will be demonstrated that he can utilize a greater number of words in writing or speaking than that great master of drama, but only that he really has a knowledge of a very much greater number of terms than the former is known to have employed in his written productions. The short description of some results the present writer has obtained in this field will give a semblance of veracity to these statements.

The statements I have read concerning the extent of vocabularies known or used by humans served to make me quite curious concerning the exactitude of the results and methods used to obtain them. Many of the estimates seemed to be no better than mere guesses and the results secured by some very good tests appeared to fall short of those which might have been attained had other methods been employed. Consequently I undertook to make a test of the extent of my own vocabulary, that is, of the number of words I can fairly claim to have some considerable knowledge of.

The dictionary employed in making the test is the Standard unabridged of 1922. This lexicon contains 2,737 pages, each page containing three columns of words. The words of these columns appear in two different situations: those

heavy type words set even with one another at the left margin; and non-marginal words, such as synthetic and compound words, and many proper names, phrases, etc. One kind of synthetic words is built out of such more elemental words as accent, abolish and the like by annexing prefixes or suffixes. Another kind is made by compounding some marginal word with other words.

The first estimate concerned the marginal words. It was conceived that if enough columns to fill fifty-two pages, or an average of two pages for each of the twenty-six letters of the alphabet, were examined, a sample sufficiently large would be obtained to be representative of all the columns of the lexicon. However, it seemed more scientific to select columns under each letter in the proportion each such letter's number of columns bears to the total number of columns. This gave to such letters as *x* and *z* only a part of a column and to such as *c*, sixteen, and to *s*, seventeen columns; but no letter was assigned less than one column. The particular columns to be employed under each letter were chosen by the hit-and-miss plan in order to secure purely arbitrary and random sampling, thus obviating personal bias. Then the words about which I knew much or considerable were marked, the total number of words in the column were counted, and the results were tabulated column by column until the total 159 columns had been covered. The total number of words counted was 4,019, the number known was 1,150, 28.66 per cent. It was estimated from the average number of words per column counted that the dictionary contains about 209,000 marginal words. It was assumed that if one knows 28.66 per cent. of the large sample of over four thousand words, he will know the same proportion of the 209,000 words. In this case the number of marginal words known was 59,800.

Since a full explanation has been made of the method used to secure an estimate of the proportion of known marginal words contained in the dictionary columns, it will be sufficient to state that the same general method was followed in securing an estimate of the known words of all the non-marginal terms. The editors of the Standard indicate that the particular edition used to make the test contains 450,000 words. We noted that the total number of marginal words amounted to about 209,000. This would leave about 241,000 of the non-marginal kind. The percentage of words of this kind which were known was found to be 28.2, or almost the same as the proportion of the marginal sort. Applying this percentage to 241,000 yields the total number of this kind of words that are known, which was 68,000. And now totaling the two estimates, 59,800 and 68,000, we have a grand total of 127,800 words known.

In consideration of the other estimates that have been made in the past, this number seems enormous. Some may be inclined to discredit the estimate altogether. Before doing this, however, let the reader observe two cautions: First, take the time to give the method used here a fair test by applying it to himself. It is likely that then he will be satisfied that this estimate may not be far wrong. Second, then consider that a large number, probably far the larger number, of known words are forms or derivatives of more elemental words. Think of *circum* in combination with a lot of other elementary words whose root meanings are known, resulting in *circumvent, circumscribe, circumambulate, circumlocution,* etc., etc. Then recall such a word as *accent* and what derives from it: *accent, accentuation, accentual, accentualist, accentually, accentuality, accentuate, accentuable, accentuation, accentus.* It is pretty certain that if one knows *accent* about all the other forms

of that word are known. And what is true of these forms of words is also true of compound words and of phrases.

So far, I have been able to induce only two persons to apply this test to themselves. It requires much time and persistence, so that few have the requisite scientific curiosity to carry it out. But fortunately, two of my very mature students, graduate men in their thirties, have made estimates. One used a Practical Standard Dictionary containing 140,000 words. He selected two pages under each letter of the alphabet by the hit-and-miss plan for counting purposes. He found he knew 2,055 of the 4,368 words contained in the fifty-two pages employed, or 47 per cent. This yielded a total of 65,800 words out of the 140,000. Had he employed an unabridged dictionary, the number he knew might have been considerably swelled.

The other student made use of an unabridged Standard dictionary of 2,757 pages. He considered both marginal and non-marginal contents. His estimate of known words in the entire dictionary was 52,489.

It is noted that the vocabularies of the students are only about half as large as the vocabulary of the first estimate. Perhaps this difference may not appear as evidence of the incompetency of the method when it is known that the one who made the first estimate has been a student during a rather mature life-time and has a command of languages the others do not possess. But one must expect variations even in the estimates made by those of about the same degree of culture because of the fact that there is no absolute criterion of the degree of knowledge which is to be applied in selecting the words which are to be considered as known. Two persons might have the same knowledge concerning a given word and one would class it among his known words and the other among his unknown words. This is a difficulty which it would be hard to overcome. Nevertheless, it is probably not a very important difficulty.

TROPICAL MEDICINE[1]

By Professor ALFRED C. REED

UNIVERSITY OF CALIFORNIA

JUST what is tropical medicine? Why should people in these United States be interested in such a thing and especially what does it have to do with California and the Pacific Coast and the Pacific Ocean? To answer these questions is to bring up one of the most romantic and interesting fields of human activity which has found a place in modern life. Medicine means more than giving drugs. In fact, drugs have a rather small part in it. Medicine means the prevention, cure and alleviation of disease. The proof of the correctness of this definition is to be found in Webster. And when we qualify this by saying tropical medicine, we mean simply the prevention, cure and alleviation of disease in warm climates. That is a subject big enough, important enough and withal sufficiently spiced with human interest, romance and practical necessity to engage the attention of every person, no matter what his creed, education or politics. All that makes for health preservation and prevention or cure of disease in hot climates comes within the realm of tropical medicine. And then, when we remember that in California especially we have all the essentials of a tropical climate and that many diseases ordinarily considered tropical are found native to this state, we can see that the subject of tropical medicine comes very near home.

In India sacred Mother Ganges receives the devotion of untold millions of her dusky sons and daughters. They come by the hundreds of thousands to bathe in her waters and worship at the thousands of temples bordering her muddy shores. In Benares, the Holy City of Hind, one sees these hordes, men, women and little children, bathing, drinking, immersing themselves and taking carefully home to their own villages earthenware vessels of the sacred water. Then the scientific Westerner looks closer at the sacred water itself and sees dead dogs, cats and rats floating in it. He sees a vilely dirty, sluggish river receiving the sewage and garbage of great cities; the half-burned remnants of the many funeral pyres on its banks; the effluvia of millions of diseased humans, and its filthy flood he finds to be a warm teeming culture medium transmitting disease in wholesale quantities to these misguided but undoubtedly sincere worshipers. That is why cholera, plague and many another disease also call the Ganges "mother" and here is found one of the world's sources of untold disease, corruption and suffering.

These Hindus do not believe in disease. They do not believe that anything in this world is material or other than illusion and, as a result, they, their children, their friends, neighbors and all with whom they share their cherished earthenware vessels of sacred water from the Ganges go down to death from preventable, unnecessary diseases, which Western science has largely eliminated by study of the natural history of the germs and parasites which cause these diseases, and by means of medically inspected milk and water supply. But the religious beliefs of the populace are an insurmountable obstacle to doing such things in India except to a very limited degree. In fact, the British in India find themselves in somewhat the position of the forty-niner who got the grizzly by the tail and dared not let go. Native superstition, tradition, religious

[1] From the Pacific Institute of Tropical Medicine.

belief—all are deadly foes of sanitary improvement. Education comes slowly. The fight of tropical medicine to prevent preventable disease, to cure curable disease and to alleviate all disease is waged against tremendous odds. This, to be sure, adds to the glory of the combat and leads the forces of science to offer many a sacrifice of brilliant men and devoted women. But it also postpones the day when mankind shall profit by the knowledge now available making for better health, happier human lives and more efficient industrial enterprise. These obstacles, of one kind or another, found in all tropical countries, are a constant lure to the adventurous, lending glamour and romance accompanied by deadly peril to the work of tropical medicine in tropical climes.

In the memory of our fathers, yellow fever was a terrible danger, invading the United States even as far north as Philadelphia and devastating the country with death and ruin in its wake. Commerce stopped. Cities were ruined. The rich and the poor alike fled unsuccessfully from "Yellow Jack." Then, in 1900, came the epochal experiments of the Army Yellow Fever Commission in Cuba, supplying proof that "Yellow Jack" was carried from victim to victim in only one way—by the bite of certain species of mosquitoes. Dr. Carlos Finlay and a few others had suspected this for many years. Drs. Lazear, Carroll, Agramonte and Reed proved it beyond a cavil. They and the brave volunteers who submitted to infection were medical heroes and some became martyrs. Then the late Dr. Hideyo Noguchi after long experiments in South America believed that he found the exact germ which caused yellow fever. But last year Noguchi and three other physicians, working fearlessly in the tropical heat of Africa, found that the cause was not yet discovered and laid down their lives as the price for knowledge which now seems to open the way for the real conquest of "Yellow Jack." For several years medical sanitation and scientific mosquito control seem to have eradicated the disease from the Western world where its stronghold had before seemed impregnable.

But in the last two years a great and unsuspected source of yellow fever has been found in West Africa, where several varieties of monkeys have been found to be susceptible, and it seems probable that a great animal reservoir exists from which the contagion spreads to man. The disease reappeared last year in Brazil, and a similar situation may also prove to obtain in South America.

An instance of how an ancient and dangerous disease has deserted cold climates and become truly a tropical disease is seen in the case of leprosy. Today leprosy is rampant across tropical Africa and is wide-spread in nearly every tropical country. Our knowledge of leprosy has advanced along two lines recently. First, effective treatment is possible, so that the active stages can be relieved and the disease arrested. This by allowing patients to be returned to their homes and occupations does away with the terrible hopelessness of leprosy. Second, leprosy is apparently a soil infection contracted through cuts and abrasions of the skin and, while many persons are infected, in the majority it lies dormant just as in the case of tuberculosis. It is thus not contagious from man to man unless under very exceptional circumstances.

There are many great tropical diseases which do not occur endemically in cooler climates but which from time to time may invade the United States or be carried over in patients from the infected regions. Kala-azar, the black fever of China and India, is one of these. It is caused by a microscopic

animal parasite which invades the blood and tissue cells. It is curable by proper treatment. It is carried from man to man by a species of sand-fly. A first cousin of this parasite causes Oriental Sore, so common in the Near East and around the Mediterranean.

African sleeping sickness, which has no relation whatever to what is called sleeping sickness in the United States, is caused by a microscopic animal called a trypanosome which invades the blood stream and central nervous system. It has depopulated vast areas in central Africa and made it impossible for man or animal to live there. These are illustrations of the enormous practical need of tropical medicine and its great importance to-day in warm climates.

In the jungles and rice-fields of many lands insect life swarms in unbelievable abundance. Among these insects, as, for example, mosquitoes, biting flies, sand-flies and ticks, are to be found the carriers and intermediate hosts of many dangerous maladies which are best combated by attacking these so-called vectors through sanitary engineering, protected water and food supplies, insect quarantine and means of avoiding bites. In no other field of medicine are so many specific cures and effective treatments known as in tropical medicine.

We in California are far from being isolated from tropical diseases. We vie with the Ganges, Turkestan, the Trans-Baikal and a spot in Africa in having a focus of bubonic plague in our ground squirrels. Human cases of plague have occurred in California each year since 1908 which were due to this source of infection. Malaria is still a factor in public health in this fair state. Rocky Mountain spotted fever is found and also the plague-like rabbit disease called Tularemia, named after the Tulare swamps where it was first identified. We have many of the numerous forms of fungus infections so common in the tropics. One of these, coccidioidal granuloma, is similar to tuberculosis and is more common in California than anywhere else in the world. In the realm of intestinal parasites we are also well supplied. Amebic infections are common and many first cousins and relatives. Round worms, tapeworms, leaf-like worms, as well as hookworm, trichina of uncooked pork and even rare tropical filarial infections are often seen. Pellagra, scurvy, beriberi and sprue claim their victims. So that altogether California is a fair field in itself for the practice of tropical medicine. Its position as the western gateway to the Orient and the Pacific islands and its increasing commercial relations with Spanish America serve to increase the variety and abundance of exotic diseases already present.

No disease that ever afflicted mankind can exceed in its toll of death, suffering, invalidism and wrecked nations and civilizations the ravages of malaria. This disease is still the major enemy in the tropics and entitled to be called the "Captain of the Men of Death." From the mangrove swamps and paddy fields of the equatorial belt to our own southern states and west to California, malaria is a pestilence that walketh in darkness, borne by more than thirty kinds of anopheles mosquitoes. Greece and ancient Rome fell before its sway. Its cost in lives and money to-day is stupendous and the problem of its control is far from solved. Sanitation has accomplished wonders in special localities but alone is insufficient to meet the need. Sanitation and mosquito control are terrifically expensive, and the world needs nothing less than the complete eradication of malaria before warm climates will be safe for human work and living.

Dysenteries are caused by many different agents, but the largest groups are due to the dysentery bacilli and to

amebas. Both of these are frequent in the United States, and bacillary dysentery is often seen in children. Undulant fever was originally called Malta Fever because it was discovered in the Island of Malta, where it was caused by germs in the milk of infected goats. It is wide-spread now over the United States, especially on farms and in rural communities. Its germ is transmitted in goat's milk to a minor degree, in cow's milk and by hogs. Milk which has been pasteurized or which is produced in properly inspected dairies is safe. Undulant fever somewhat resembles typhoid and may persist in recurring waves for six months and even a year. Such diseases as infectious jaundice, rat-bite fever and relapsing fever appear from time to time in the United States.

It is hardly realized that rabies (hydrophobia) is wide-spread and dangerous in nearly all tropical countries. This is due to the fact that most native races see no sense in control or care of dogs, which consequently run wild and are usually diseased and half-starved. In Hindu and Buddhist countries especially no dog may be killed, even though no one feeds or cares for it. Under these conditions dog-bite is common and human rabies is a frequent result. Nearly every large tropical city has its Pasteur Institute engaged in the manufacture of the Pasteur treatment which prevents rabies. To these centers people come by the thousands from many miles around. Even in China rabies has been known since early historic times. The only means of prevention known after an infected bite is by the Pasteur treatment. These institutes also manufacture anti-venins against snake-bite and various vaccines and protective sera. Their influence is wide-spread. The value of their ministrations is attested by the great demand on the part of native populations, who know all too well the dangers of these diseases, from rabies to smallpox, and who really and pathetically appreciate the opportunity of avoiding them.

Problems in untold numbers of disease prevention and health preservation in the Orient and in hot climates are fascinating, practical, new and awaiting solution. Nowhere else do achievement and human service offer greater inducements than here. The scientist in nearly every line is concerned. The nurse, the laboratory technician, the builder, engineer, statesman, administrator, business man, missionary, soldier, sailor, traveler—each and every one has a vital stake in the struggle of tropical medicine to make hot climates safe for man and to make man safe to go into hot climates after their treasures of wealth, experience, science and travel.

Man, doubtless, began his activities on the earth in regions corresponding in warmth to the present tropics. For two reasons he moved away from these languorous lands. In the first place, the hardier, more roving and more intelligent of mankind were led, among other things by their curiosity, to seek cooler localities where, thanks to a tougher fiber, they survived. This more resistant, energetic and adaptive portion developed under the stimulus of changeable climate and the need for securing food and shelter under more difficult conditions. In the second place, insects, poisonous animals, snakes, fungi, bacteria, protozoa and a host of other enemies of man also developed in the warm moisture of the tropics and thus the mass of disease causes became rank and luxuriant so that man could not rise above them. All his racial energy was spent in trying to maintain mere existence, leaving none for intellectual and spiritual progress. But the contest was unequal and tropical man either died out, migrated or remained savage.

To-day, recognizing this old historical record, man is faced by a population in

temperate climates beginning to approach the limits of available food supply. He needs more room for living purposes, more food, more power, more of the innumerable luxuries and necessities associated with culture and intellectual improvement. All these things may be had, one way or another, in the low altitudes of the tropical belt. Therefore, almost instinctively, we are turning to tropical enterprise and development, facing squarely the great problem as to how the tropics can be made safe for civilized man and developed to produce what he needs for still further advancement.

So true is this trend, so clear the need in the eyes of commerce and statecraft, that we find great institutes of tropical medicine established as centers for the education of physicians and nurses, for study of special problems of medical and commercial importance and for treatment of patients. Such is the splendid Tropical Institute of Hamburg, supported by the German government. Here in this great, flourishing German port is a splendid tropical hospital, research plant and school for physicians. Such is the excellent and, in this country, little-known Tropical Institute of Amsterdam supported by the Dutch government as a necessary adjunct for its great colonial empire in the East Indies. Such also the institutions in Paris, Brussels and Rome.

England has four schools of tropical medicine. Of these the largest and best is in London, where twice a year a class of seventy-five physicians spends five months in the graduate study of tropical medicine and hygiene. Near the London school is the wonderful Wellcome Museum of Tropical Medicine, a remarkable teaching exhibit which illustrates graphically with charts, photographs and specimens of its ravages, the cause, transfer, geography, symptoms and epidemiology of each tropical disease. Such a museum is a splendid nucleus for the teaching of any science, especially tropical medicine. London lives by the sea and its vast sailor population requires a series of hospitals in which all manner of tropical maladies are constantly seen.

In the tropics are many splendid medical centers and hospitals. The United Fruit Company has an unexcelled system of hospitals in the ports of the Caribbean Sea. The Canal Zone and its excellent hospitals administered by the U. S. Army Medical Corps are well known. The Oswaldo Cruz Institute for Medical Research is one of the outstanding features of Rio de Janeiro. Cairo with its hundred-year-old hospital of eight hundred beds is a noted center for wide-spread modern methods of disease control. In addition to the clinical care of patients carried on in the medical stations of the Hadassah movement throughout Palestine, the Hebrew University of Jerusalem is turning out excellent scientific studies. The best medical school in the Near East is at the American University of Beirut.

Bagdad has an excellent hospital, research plant and Pasteur institute, and is opening a medical college. In India there are numerous centers of first-class medical work. The crown of them all, however, is the Calcutta School of Tropical Medicine, founded by Sir Leonard Rogers. This school is unexcelled in the world. It has an unusually able faculty and a large tropical disease hospital. Its service to patients is very large. Twice a week some three hundred lepers come to the leper clinic alone where they are rapidly made noninfectious, so far as possible kept at regular employment, allowed to live with their families and are treated like human beings.

Rangoon, Colombo, Singapore and Kuala Lumpur in Malaya are outstanding for their medical facilities and ser-

vice. Space allows only mention of the various centers in Australia and in Java. Manila has wonderful facilities and material, largely centered in the Bureau of Science and the University of the Philippines. The great Culion Leprosy Station is a monument to American medical science and is being made a memorial to General Leonard Wood. Two millions of dollars are now being raised to make this station wholly adequate and to allow the fullest advances in treatment and prevention of this ancient enemy of man. No more worthy enterprise is before the American public to-day. Professor David P. Barrows, of the University of California, is among the best-informed Americans to-day on Philippine and Pacific Ocean relations. His endorsement and leadership of the Leonard Wood Memorial Fund speaks for itself.

Honolulu, with its modern and complete Queen's Hospital, has an excellent, though small, center for study of tropical medicine. China, the future arbiter of the Pacific, has in Shanghai the medical department of the Central Nationalist University and in Peking the Rockefeller-endowed Peking Union Medical College, both of which are leading in the great field of disease control in China.

So we come back to the United States and find several universities on the east coast developing strong departments of tropical medicine, such as Harvard, Columbia and the Johns Hopkins. Tulane University in New Orleans devotes much attention to this important subject. Everywhere commerce, business and government are recognizing that more and more mankind must live in close relation with, if not in, the tropics.

Until recently there was no center on the Pacific Coast for this type of work. Now in the University of California there has been established the Pacific Institute of Tropical Medicine at the Hooper Foundation in San Francisco. This is in close association with the University Medical College, but is a separate graduate school. The Tropical Institute of the University of California is organized for three types of work.

(1) Regular courses in tropical medicine and hygiene are given for physicians. Young doctors going out to commercial stations, government service or missionary work in the tropics or the Orient can here secure training in the specialized kind of problems they will have to face. Practicing physicians in those countries can here secure a complete and up-to-date review. (2) Research is carried on in connection with tropical diseases and hygiene, problems arising from shipping and passenger traffic, cargo spoilage and contagious diseases on shipboard. Special studies are being started on tropical drugs and in connection with tropical food supplies. (3) Facilities are provided for the diagnosis and treatment of patients suffering with any kind of tropical, Oriental or exotic disease. In addition to these features, classes are available for non-medical persons intending to live or travel in the tropics or the Orient. Here special instruction is given in simple language on health preservation, personal hygiene and disease hazards in those places.

The stories of Herman Melville, Captain Cook's voyages and the works of Alfred Russell Wallace are literary classics which afford an insight into many practical problems of tropical medicine. It is no small job to avoid sickness in a ship's company, and when contagious disease appears on shipboard difficulties multiply. Yet, no sane person wants to travel on a ship where there is not adequate provision for proper handling of such emergencies. International and United States quar-

antine requirements must be met. These all have to do intimately with tropical medicine.

Quarantine to-day is designed to operate with as little impediment as possible to commerce and passenger traffic. By observance of definite scientific rules, delays are avoided and disease is not introduced. The splendid national quarantine system of the United States, conducted by the federal Public Health Service, is responsible for the fact that in the past generation cholera and yellow fever have been unknown in this country. Smallpox, leprosy and plague are equally well excluded, but unfortunately these diseases are already endemic in the United States.

Enough has been said to give some idea of the scope and importance of tropical medicine to the world to-day and especially to the west coast of the United States. The preservation of health and the treatment and prevention of disease in hot climates hold a lure for the student, the physician and the scientific worker that is exceeded only by their practical importance for the average citizen.

THE SIGNIFICANCE OF BOUNDARY CONDITIONS IN PHYSICS

By PROFESSOR R. B. LINDSAY

SLOANE PHYSICAL LABORATORY, YALE UNIVERSITY

THE expression of physical laws in differential form is one of the most fundamental features of theoretical physics, and a discussion of the meaning of this process should always form an important part of the foundations of the subject. A number of points arise over which the beginning student is rather apt to be puzzled. Not the least significant of these is the following question: why is it that the general solution of a partial differential equation in physics is so seldom of concrete use to the physicist? To understand the meaning of this question more precisely let us consider the time-honored case of a transversely vibrating string. Applying the usual dynamical analysis to a differential element of the string we obtain the usual second order linear partial differential equation of motion. The general integral giving the displacement from its equilibrium position of any point of the string at any time is then found to be of the form $f(et - x) + F(et + x)$, where x denotes distance measured along the string from some chosen origin, t is the time and e is a definite function of the tension and linear density of the string; finally f and F are two perfectly arbitrary functions of the arguments in the parentheses. Mathematical examination of this result then shows that there is wave motion along the string in both directions with velocity of propagation equal to e. But surely we do not need a mathematician to tell us that if we shake a string waves will move along it! We can see that without the mathematical analysis. The only specific thing we learn from the general solution is the dependence of the velocity on the physical properties of the string. How can we obtain more concrete information about the string's behavior? Evidently only by assigning certain special conditions which the general solution must satisfy. These are the so-called "boundary conditions." Let us look into their fundamental nature and their meaning in physical problems with some detail.

Continuing our study of the string we see that we can at once render the problem more specific if we confine ourselves to motions which are simple harmonic in time. The functions f and F entering into the solution are then restricted to the circular type (*i.e.*, sine or cosine). But even the imposition of this restriction fails to specify the answer to the question which in a case of this kind the physicist feels bound to ask: *viz.*, at any instant of time what is the exact state of motion of every part of the string? For the solution still contains four arbitrary constants or parameters. To specify these, further conditions are necessary involving assumptions as to the state of motion at some definite point or points of the string at some definite instants of time. The reader will recall that two of these constants may be fixed by the assumption that the string has a finite length and that no motion ever takes place at the ends. The final answer to the physicist's question becomes possible only when we have the following additional information, *viz.*, an instantaneous photograph or snapshot of the whole string at some initial instant, as well as the velocity with which every part of the string is moving at that instant. Incidentally the assumption of

rigidly fastened ends leads to another important result: it says that the possible frequencies of free oscillation (*i.e.*, the oscillation resulting when the string is struck or plucked and then let go) are limited to a discrete series—the so-called harmonies. We need not go into further details about this well-known problem, but may summarize by noting that the introduction of the boundary conditions into its general solution has accomplished for us the following three noteworthy things: (1) specified the type of mathematical function to represent the physical disturbance; (2) evaluated the arbitrary constants appearing in the expression for this disturbance; (3) introduced a certain characteristic discreteness into the resulting motion. It is just these things which are necessary in the answer to the physicist's desire for concrete knowledge, as expressed in the question stated.

The above simple illustration makes it evident that the boundary condition concept is an extremely significant one in the development of mathematical physics. It is perhaps worthy of more extended study and a consequent extension of meaning over the restricted use generally current in physical literature. It is thus the purpose of this article to interpret the concept in the broadest possible sense to see what unifying light it casts on the subject of mathematical physics as a whole. Proceeding from this point of view we shall divide such conditions into two classes, the specific and the general. A specific boundary condition is simply a postulated physical event in space and time, expressed by the requirement that a certain physical quantity shall have a definite value or set of values throughout a certain region of space within a certain interval of time. This definition includes the well-known "initial" conditions of classical physics and absorbs them into our more extensive concept. On the other hand, by a general boundary condition we shall mean any fundamental restriction on the type of behavior of a physical system, expressible by means of a mathematical relation among a set of physical quantities characteristic of this system. It may thus be itself a physical law but is more apt to be a general condition which all possible physical laws for a given system must satisfy, thus transcending the special laws. We have in mind here such fundamental postulates as the quantum conditions in atomic structure theory and the requirement of invariance with respect to transformations of coordinates so prominent a feature in the relativity physics. These are not generally emphasized as boundary conditions, but we shall see that there is a certain gain in unity of thought by so considering them.

For the moment let us give some attention to the specific type of condition. From the mathematical standpoint there is perhaps nothing very striking about this type. Specifying a set of events in space and time yields a system of equations from which the arbitrary constants of the general solution of an appropriate differential equation can be evaluated. But from the physical standpoint it seems that rather more is involved. For the necessity of the boundary condition tells us that in order to predict the future behavior of a physical system we must know not only the differential law according to which the system changes its state: we must also have definite knowledge of its state at a certain specified time or at any rate some property of the system expressible by a set of physical events. It is only where such knowledge is available that the concept of causality has any practical significance in physics. One more well-worn example suffices to emphasize this point. From the fundamental dynamical laws and the law of force we are able to compute the position of any particle in a central force

field at all times past or future (and incidentally the type of orbit traversed) as soon as we know its position and velocity at any single instant; neglecting the practical difficulties in the reduction of observations, we have here the theoretical basis of all calculations of astronomical tables. Other illustrations of like character will occur to the reader.

This is a good place to focus attention on a large class of problems peculiarly noteworthy because of our ignorance of the appropriate conditions. Consider a mass of gas, which from the standpoint of the kinetic theory is assumed to consist of an enormous number of molecules moving in straight lines in every direction with varying velocities, colliding frequently with each other and the walls of the confining vessel. It is postulated that each molecule is a rigid sphere and that its motions are governed by the ordinary laws of collisions in mechanics. It would seem a comparatively simple matter in principle though perhaps time-consuming in practice to compute the position and velocity of each molecule from the above assumption. But we are forgetting the boundary conditions! In order to make these calculations we must know the state of the system of particles at some definite time. This is, however, a hopeless task. We simply can not hope to know exactly the boundary or initial conditions in a case like this where the number of entities is so great. What then do we do? In such a problem we invariably fall back on probability considerations. We cease to fix attention on the individual member of the aggregate and concentrate on the average, employing the principle of "large numbers," *i.e.*, the method of statistics. The fundamental meaning attached to the employment of probability in physics is thus intimately bound up with our knowledge or ignorance of boundary conditions. Thus, according to Poincaré, in our consideration of the behavior of any physical system, we may distinguish three degrees of ignorance: the first, in which we know both the laws in accordance with which the system changes and the appropriate boundary conditions, and hence in all strictness have no need for probability save what our laziness suggests; the second, much more common, in which we know the laws but are ignorant of the conditions (as witness the above example), and the third, in which we know neither the laws nor the conditions. As a matter of fact, no physicist ever remains content with this third degree of ignorance; he always proceeds to postulate possible laws to which probability calculations may be applied in an effort to understand the phenomena in question. So we may really consider as an important element in the distinction between a dynamical theory and a statistical theory the possibility of assigning definite boundary conditions in the former case and the practical impossibility of carrying out this step in the latter case.

Boundary conditions of this type are obviously closely connected with the possibility of measurement (whether real or ideal), for fixing an event for physical purposes implies observation and measurement. If the event in question deals with an enormous number of entities we are naturally led to feel that although the measurements specifying the conditions may be carried out in principle the task is too complicated and involved to be of practical utility. Interestingly enough this matter is receiving considerable attention in the more recent atomic structure theory. The fruit of the endeavor to inject more concreteness, greater "Anschaulichkeit," into the matrix quantum mechanics has been Heisenberg's "principle of indeterminism," which states with ruthless definiteness that we can not hope to carry out to indefinite precision the measurements fundamental to the fixation of the boundary conditions even in principle, no matter how small the number of entities may

be. Putting the matter specifically, suppose we wish to measure the position of an electron in an atom with great exactness. According to the principle we are then forced to sacrifice precision in measuring its velocity, *i.e.*, we must remain content merely with the probable value of the latter, or with the probability that the electron shall have a velocity lying in any assigned interval. Thus the principle maintains that it is impossible to measure both the position and the velocity of an electron simultaneously with the same degree of precision. It is clear that acceptance of "indeterminism" in this sense puts our ignorance of the necessary boundary conditions in the atomic domain on a quite different basis from the probability considerations we have just been discussing. There the disregarding of the boundary conditions and the reversion to the study of average behavior were the dictate of economy, convenience and simplicity. Here, however, our procedure is to be governed by necessity. In admitting that even when one particle is under consideration we can never know the boundary conditions necessary to a complete knowledge of its behavior in space and time, we are proceeding from the state "ignoramus" to the greater extreme "ignorabimus" (du Bois-Reymond). The physicist is bound to ask himself the question, is such a procedure calculated to advance the science? To embark even on a beginning to the answer to this question would carry us too far into the complexities of quantum mechanics. But no matter what our attitude may be toward the "indeterminism" principle, it must be admitted as an interesting illustration of what our conception of boundary conditions in microscopic phenomena may eventually become.

So far in our study of specific boundary conditions we have confined ourselves to discrete events, such as the position or velocity of a system at some definite instant. But this is not the only case of interest. Boundary conditions need not be discrete but may cover a continuous range. Consider a fiber which is twisted from its normal equilibrium configuration by the application of torque. When released it displays the familiar phenomenon of elastic fatigue and hysteresis. But this means that a knowledge of the state of twist and angular velocity of the fiber at any instant is not competent to enable us to predict its state and motion at any subsequent time. To answer the usual question here we must know the whole history of the fiber since first it began to move at all, *i.e.*, we must be acquainted with its heredity. The boundary conditions in this case must thus extend over continuous intervals of space and time. The name hereditary mechanics has been given to the field of problems into which such conditions enter. It is obviously only by means of an integral extended over the lifetime of the system studied that such a boundary condition can be expressed mathematically. Thus it is that integral equations have come to be of great service in physics.

There is a large class of extremely important physical problems which involve the flow of energy across the interface of two media. We here encounter a kind of boundary condition which is different from the specific type we have just been discussing. Thus at the interface we find it necessary to postulate a certain continuity for the functions representing the disturbance which is being propagated. It is not that we specify the exact values at the boundary; rather certain relations must hold among the physical quantities characteristic of the disturbance in the two media at the boundary. Hence we may look upon this type of condition as more general. Thus, to seek a simple illustration, when a sound wave traverses a tube in which there occurs an abrupt change in cross-section, we require that at the place where the change occurs there shall be

continuity in the pressure and the volume displacement of the air disturbance. This assumption leads to the correct experimental value for the fraction of the incident sound energy which is transmitted across the junction. Situations essentially not at all different are met in the behavior of light and all electromagnetic radiation at an interface. The imposition of the continuity conditions serves to fix the distribution of energy in the reflected and transmitted beams. As a matter of fact, often more than this is involved: the familiar law of refraction (*i.e.*, the law of Snell) for an obliquely incident beam can be shown to follow from the mere fact that some condition must subsist at the boundary and is independent of the precise form of this condition.

In the above illustration, then, we have an example of the general boundary condition, namely, a fundamental restriction on the type of activity possible for the system considered. Thus when wave energy passes through a region, just as soon as a boundary is encountered, the propagation of the disturbance is profoundly modified. In place of, let us say, a single progressive plane wave in one direction we must now have waves in both directions (or in certain cases, in every direction); the whole motion pattern is altered, and all as the result of the continuity condition associated with the presence of a boundary. Exactly the same kind of thing is met in the case of the vibrating string when the ends are fixed. For the condition of no motion at the ends is precisely a continuity condition at a boundary, though of a special type. Incidentally, this condition is peculiarly important, because as we have seen in our example, it serves to introduce discreteness into the motion by limiting the possible frequencies of simple harmonic vibration to a certain definite series of values, the so-called "characteristic values." The general problem of which this is a special case has long had a particular charm for mathematicians; it is only within the past three or four years that it has assumed unusual importance for physics with the advent of the wave mechanics in atomic structure. For in the recent theory of Schrödinger the possible states in which an atom may exist are represented by the solutions of a certain wave equation (not dissimilar in form from that of a vibrating medium, like a string, but differing from it in the interpretation of the quantities involved) satisfying the boundary condition that they shall remain finite, continuous and single valued throughout all space and be zero at infinity. It then develops that, as a result of this condition, the principal parameter of the equation, representing the energy of the atom (and corresponding to the frequency in the analogous problem of the vibrating medium) is in general restricted to a discrete set of values. In the cases so far studied, these values are precisely the correct energy values indicated by experiment for the possible stationary states of the atom. It is difficult to resist the feeling that the discreteness introduced by the above boundary condition is intimately connected with the discreteness which we ought to expect to be physically characteristic of an atomic mechanism, and which is indeed one of the most striking experimental facts about all atomic phenomena. It is improbable that the final physical interpretation has been given to either Schrödinger's wave equation or the boundary condition restricting the solutions. But no one can question the tremendous importance of this boundary condition to the final result, and so it marks a definite extension in the significance of this conception in modern physics.

It is indeed true, as the reader who is familiar with the history of recent atomic theory will recall, that the classical Bohr theory of the atom employs a boundary condition which achieves essentially the

same end as the boundary condition of the Schrödinger theory, with, of course, distinctive differences in details which have seemed to favor the latter. To be specific, it will be remembered that the Bohr theory postulates that in an atom the electrons move in accordance with dynamical laws, but from the whole continuum of possible mechanical orbits it selects as actually existent those only for which certain path integrals of the component momenta are equal to integral multiples of the fundamental constant of Planck. Here again discreteness is introduced into the problem. The energies of the stationary states of the atom are the energies of the orbits which are allowed by the quantum condition, which is thus really just as much a boundary condition as that which must be satisfied by the solutions of Schrödinger's equation. Physically the former does not seem to be so understandable as the latter, but this means merely that we are not so familiar with conditions involving path integrals of momenta as with conditions involving continuity at a boundary in a medium, with which we have dealt throughout classical physics. But in any case the significant fact is that the desired result is secured through the agency of a boundary condition.

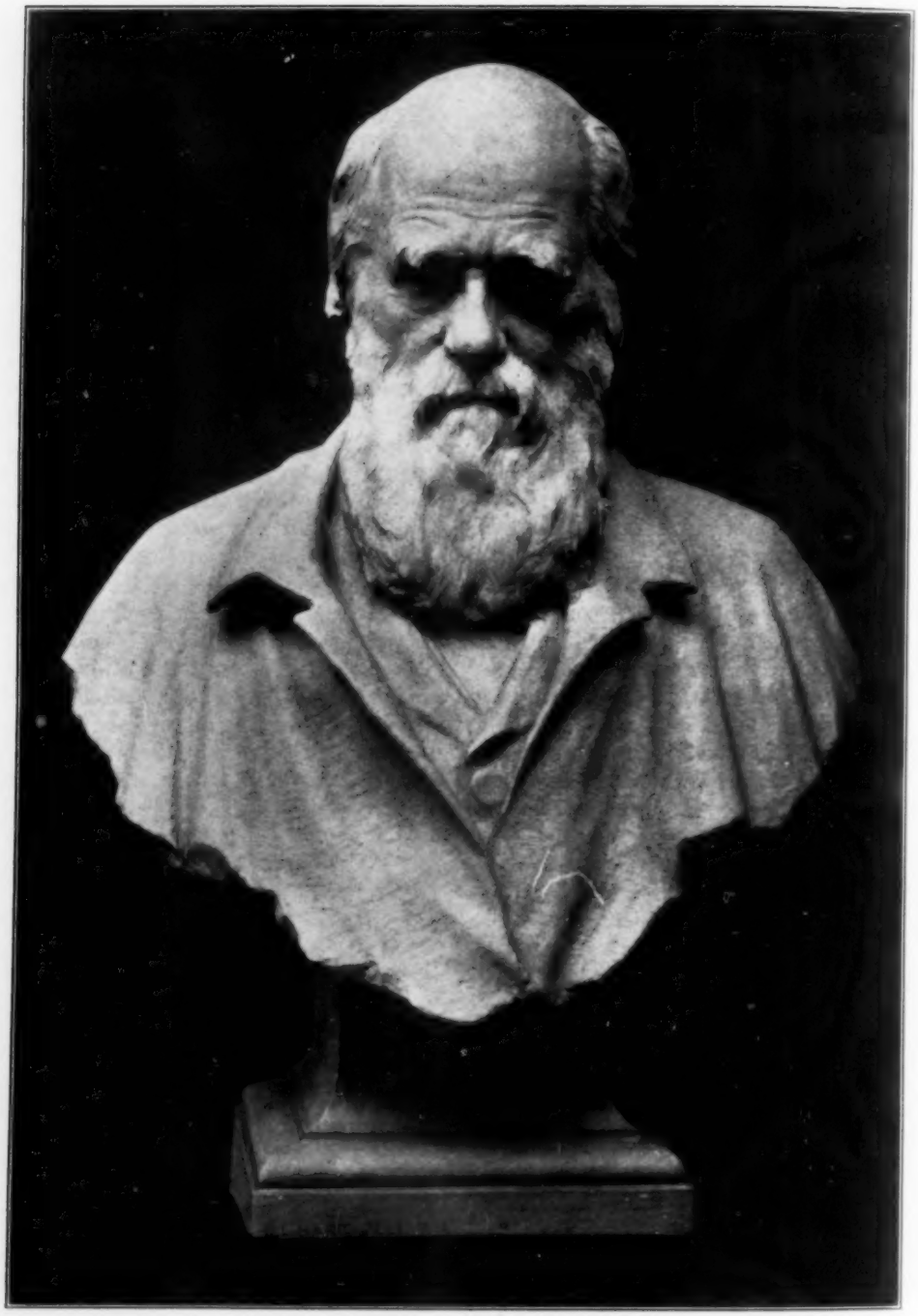
Added interest in this subject is provided by the theory of relativity, for it is through this that we may see our way to an even more general view of the nature of boundary conditions. Concomitant with the growth of this theory there has arisen the conviction that physical laws in general must be of such a character that they retain their form intact when the coordinate system in which the various quantities are expressed is transformed to another system in accordance with the now celebrated Lorentz-Einstein transformation equations, which is only the formal mathematical way of expressing the impossibility of detecting absolute motion by any means and in addition the fact that the velocity of light has the same value for any two coordinate systems moving with respect to each other at constant velocity. In the broad interpretation of this essay the invariance with respect to the Lorentz-Einstein transformation is just as truly a boundary condition as is the quantum condition. It has, to be sure, a more general scope than the latter, for it serves to select the type of physical law which is best adapted to describe successfully physical phenomena. Of still greater generality because of its larger realm of applicability is the fundamental postulate of general relativity that all physical laws must be expressed in the form of tensor equations. Here again the restriction is on the type of general law and not merely on the particular kind of behavior resulting as a special case of a given law. In this sense boundary conditions like the tensor requirement are more general than the differential equations in which the laws of physics are embodied. In truth, it would seem as if physicists were coming to realize more and more the importance of ascertaining the general boundary conditions which whole groups of physical laws must satisfy. This puts us in a position where the possible type of law is of greater significance than the specific laws themselves. From the esthetic point of view this marks a tremendous gain for science as a whole. Nor is it without utility, as is illustrated by Einstein's use of it in the discovery of the general law of gravitation.

The reader should be able to suggest to himself many other illustrations, but to render the matter as clear as possible, it is well to point out that in the view of the present article many so-called physical laws are really boundary conditions in disguise, as it were. Thus the law of the conservation of mechanical energy appearing as the first integral of the equations of motion of a conservative dynamical system is a boundary

condition in the sense that it is the mathematical expression of the fact that the system under consideration is conservative; it thereby delimits or fixes a boundary for the class of systems considered and separates them from all others. The importance of this step becomes clear when we find that many of the specific laws obeying this general condition are found to be satisfied approximately in the world of physical phenomena. And the notion of the separation of dynamical systems into conservative and non-conservative systems has been of prime importance in the advancement of theoretical mechanics.

Perhaps the most recent application of our general view is the introduction of the group concept into atomic physics by Weyl and others. This concept, in accordance with which a set of entities is said to form a group with respect to certain operations provided certain definite conditions are satisfied, has long been of unifying utility in mathematics. Its application in atomic structure theory may prove the means of providing much desired uniqueness in quantum mechanics, in ascertaining the most general types of rules under which the behavior of all atomic systems may be subsumed.

How then may we sum up the whole matter? We may say that closely associated with every physical law there are to be found important boundary conditions of both a general and a specific nature, and forming a very significant part of the physical meaning of the law as well as its practical application. The specific conditions show us how to use the law to predict physical events, and ignorance of them forces us back on probability considerations; the general conditions fix the possible types of laws or the possible kinds of functions which enter into them. The mind can conceive countless forms of differential laws. The general boundary conditions serve to pick out the useful ones. Our search should forever turn in the direction of these conditions, the discovery and clear statement of which represent the forward development of mathematical physics.



CHARLES DARWIN

BUST PRESENTED BY DR. JOSEPH LEIDY, II, OF PHILADELPHIA, TO THE BRITISH NATION, IN MEMORY OF THOSE AMERICAN NATURALISTS WHO CAME TO THE SUPPORT OF CHARLES DARWIN UPON THE PUBLICATION OF "ORIGIN OF SPECIES" IN 1859.

THE PROGRESS OF SCIENCE

THE PRESENTATION OF DOWN HOUSE TO THE BRITISH NATION

THE formal opening of Down House, the home of Charles Darwin, presented by Mr. Buckston Browne, a distinguished surgeon and student of Huxley, to the British Association for the Advancement of Science in custody for the nation, was observed under the auspices of Sir Arthur Keith, F.R.S., on June 7, in the presence of a large and distinguished audience.

Inaccessible either by rail or bus, Down, situated among the chalky uplands of Kent, has remained peaceful and unspoilt. It is as Darwin knew it, and now his own home, a fine English country house on the outskirts of the village, has been restored as nearly as possible as it was when he lived and worked there.

In the study in which Darwin wrote the "Origin of Species," there is to be seen the exceptionally high chair in which he sat, using as a desk a board placed across his knees. In the center of the room is his work-table and among the relics displayed on the book shelves are his pistols, the telescope he used during the voyage of the *Beagle*, his geological hammer and many other scientific instruments and the proverbial snuff jar. To the list of treasures there are to be added the fifty-eight original Darwin letters, known as the Müller collection, which Dr. Henry Fairfield Osborn, a former president of the American Association, is presenting to Down House.

Down House lies in the midst of beautiful gardens and orchards, and it was on the lawn that the opening ceremony was performed.

Mr. Buckston Browne formally presented the house into the keeping of the British Association.

Sir William Bragg, F.R.S., president of the British Association, accepted the gift, expressing the gratitude of the association.

Sir Arthur Keith, F.R.S., delivered the principal address, in the course of which he said:

> In Down House was enshrined the personality of a great man, one who always placed goodness above greatness. It is right that we should stress now this personal aspect of Darwin's life, for the character of no man has been so wilfully travestied in his own century as well as in ours.

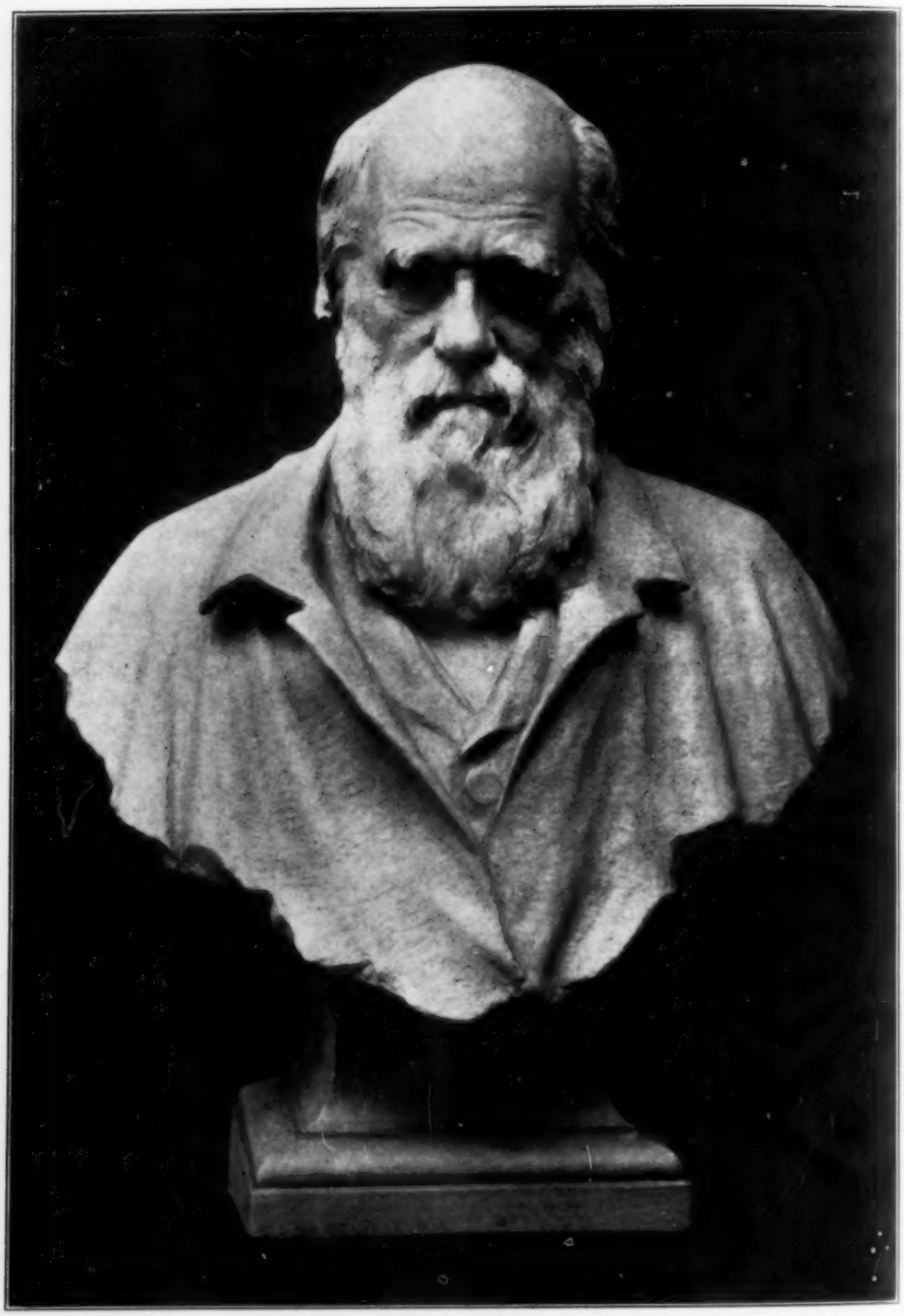
Dr. R. Anthony, who occupies the chair of the immortal Cuvier, represented France and presented the felicitations of French science.

Dr. Joseph Leidy, II, as the representative of the American Association for the Advancement of Science, presented a magnificent bust of Darwin by the gifted sculptor, Charles L. Hartwell, R.A., now on exhibition in the Royal Academy. He referred to the interesting fact that from American science came the first foreign official recognition of the "Origin of Species" upon its publication in 1859, when the Philadelphia Academy of Natural Sciences made Darwin a corresponding member upon the recommendation of Joseph Leidy and Isaac C. Lea.

Upon the announcement of his election, Darwin wrote Sir Charles Lyell, "It shows that some naturalists there do not think me such a scientific profligate as many think me here."

In the course of his remarks Dr. Leidy said:

> We wish therefore to forge still stronger the chain which links American science with Down House and this memorial.
>
> It is our great privilege to place in this shrine the fine bust of Charles Darwin as a gift to the British nation from America in memory of those American naturalists who came to the support of Charles Darwin upon the publication in 1859 of the "Origin of Species."



CHARLES DARWIN

BUST PRESENTED BY DR. JOSEPH LEIDY, II, OF PHILADELPHIA, TO THE BRITISH NATION, IN MEMORY OF THOSE AMERICAN NATURALISTS WHO CAME TO THE SUPPORT OF CHARLES DARWIN UPON THE PUBLICATION OF "ORIGIN OF SPECIES" IN 1859.

THE PROGRESS OF SCIENCE

THE PRESENTATION OF DOWN HOUSE TO THE BRITISH NATION

THE formal opening of Down House, the home of Charles Darwin, presented by Mr. Buckston Browne, a distinguished surgeon and student of Huxley, to the British Association for the Advancement of Science in custody for the nation, was observed under the auspices of Sir Arthur Keith, F.R.S., on June 7, in the presence of a large and distinguished audience.

Inaccessible either by rail or bus, Down, situated among the chalky uplands of Kent, has remained peaceful and unspoilt. It is as Darwin knew it, and now his own home, a fine English country house on the outskirts of the village, has been restored as nearly as possible as it was when he lived and worked there.

In the study in which Darwin wrote the "Origin of Species," there is to be seen the exceptionally high chair in which he sat, using as a desk a board placed across his knees. In the center of the room is his work-table and among the relics displayed on the book shelves are his pistols, the telescope he used during the voyage of the *Beagle*, his geological hammer and many other scientific instruments and the proverbial snuff jar. To the list of treasures there are to be added the fifty-eight original Darwin letters, known as the Müller collection, which Dr. Henry Fairfield Osborn, a former president of the American Association, is presenting to Down House.

Down House lies in the midst of beautiful gardens and orchards, and it was on the lawn that the opening ceremony was performed.

Mr. Buckston Browne formally presented the house into the keeping of the British Association.

Sir William Bragg, F.R.S., president of the British Association, accepted the gift, expressing the gratitude of the association.

Sir Arthur Keith, F.R.S., delivered the principal address, in the course of which he said:

> In Down House was enshrined the personality of a great man, one who always placed goodness above greatness. It is right that we should stress now this personal aspect of Darwin's life, for the character of no man has been so wilfully travestied in his own century as well as in ours.

Dr. R. Anthony, who occupies the chair of the immortal Cuvier, represented France and presented the felicitations of French science.

Dr. Joseph Leidy, II, as the representative of the American Association for the Advancement of Science, presented a magnificent bust of Darwin by the gifted sculptor, Charles L. Hartwell, R.A., now on exhibition in the Royal Academy. He referred to the interesting fact that from American science came the first foreign official recognition of the "Origin of Species" upon its publication in 1859, when the Philadelphia Academy of Natural Sciences made Darwin a corresponding member upon the recommendation of Joseph Leidy and Isaac C. Lea.

Upon the announcement of his election, Darwin wrote Sir Charles Lyell, "It shows that some naturalists there do not think me such a scientific profligate as many think me here."

In the course of his remarks Dr. Leidy said:

> We wish therefore to forge still stronger the chain which links American science with Down House and this memorial.
>
> It is our great privilege to place in this shrine the fine bust of Charles Darwin as a gift to the British nation from America in memory of those American naturalists who came to the support of Charles Darwin upon the publication in 1859 of the "Origin of Species."

DR. N. L. BRITTON

DIRECTOR-IN-CHIEF OF THE NEW YORK BOTANICAL GARDEN FROM 1896 TO 1929

DR. BRITTON AND THE NEW YORK BOTANICAL GARDEN

THE resignation of Dr. N. L. Britton as director-in-chief of the New York Botanical Garden was an event of the first importance in the botanical world and in scientific circles generally. This resignation, dated May 25, 1929, was accepted at special meetings of the board of managers and the scientific directors of the garden, held on July 8, 1929, and took effect as of August 1, 1929.

Dr. Britton was one of the prime movers in the plan to establish a botanical garden in New York City. The garden was incorporated in 1894, and on July 1, 1896, Dr. Britton entered upon his duties as the first director-in-chief, having been secretary of the board of managers for some two years preceding that date.

When the new garden was established there were only three independent botanical gardens in the United States, namely, the Missouri Botanical Garden, at St. Louis, the Arnold Arboretum, near Boston, and the U. S. Botanic Garden in Washington. At that time the general public had very hazy ideas as to what a botanic garden is, and one of the problems of the new director was to educate the lay public and, in particular, the officials of the city of New York, as to the nature, importance and needs of such an institution. In addition to this, a quite undeveloped area of two hundred and fifty acres had to be laid out, graded and planted; buildings, greenhouses and public conservatories were to be planned and erected, and, most important of all, a scientific staff had to be organized, and botanical collections assembled for scientific and educational work.

For such work something more is needed than a knowledge of plant life, and the officials of the new garden were exceedingly fortunate in having, in the person of the first director-in-chief, a man who was not only an accomplished botanist, but also an engineer and an able scientific administrator.

Pari passu with the development of the physical plant, a vigorous program of scientific research was initiated, with emphasis on systematic botany and botanical exploration in North America, especially in subtropical and tropical America and adjacent islands.

Within a very short time "New York Botanical Garden" came to mean one of the largest and strongest organizations of botanical investigators in America, and the affiliation of the garden with Columbia University favored the early registration of a large number of graduate students.

The results of research by staff and students required facilities for publica-

THE NEW YORK BOTANICAL GARDEN. MUSEUM BUILDING.

DR. ELMER D. MERRILL

WHO SUCCEEDS DR. BRITTON AS DIRECTOR-IN-CHIEF OF THE NEW YORK BOTANICAL GARDEN

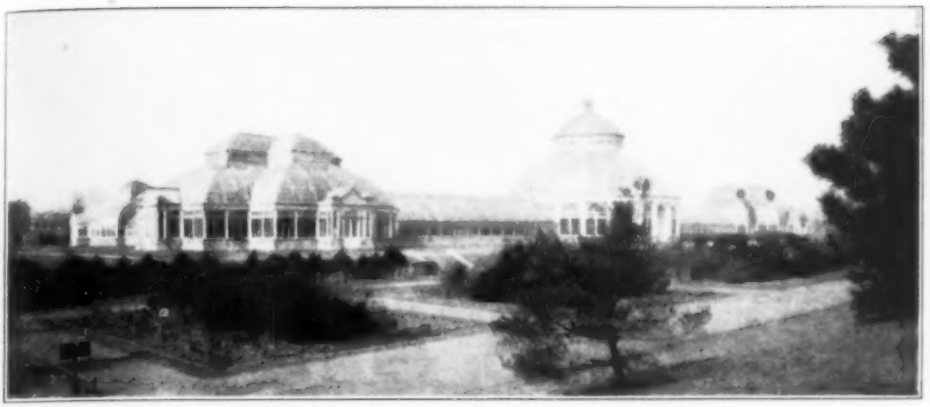
tion in addition to those already available, and this need has been met by the establishment of several serial publications which have taken their place as among the most important of the botanical world.

As a result of the extensive program of botanical exploration, and in other ways, the herbarium of the garden, comprising not less than 1,500,000 specimens, has become one of the largest and most important herbariums in the world, rich in type specimens and other valuable material. The garden library, of some forty thousand volumes, is one of the most important botanical libraries in the New World.

Under Dr. Britton's able administration, the New York Botanical Garden soon took its place among the foremost institutions of its kind, serving the local public to an extent far in excess of the public's share in the cost of maintenance, and making voluminous and substantial contributions to botanical science.

At the celebration of the twentieth anniversary of the foundation of the garden, September 6 to 11, 1915, one hundred and forty-five botanists and others were in registered attendance and many messages were received congratulating the garden and its director-in-chief on the splendid accomplishment. Volume VI of the Memoirs of the New York Botanical Garden comprises thirty-six scientific papers presented as a part of the anniversary program.

On May 7, 1919, the board of managers gave a complimentary dinner to Dr. Britton at the Metropolitan Club.



ONE OF THE CONSERVATORY RANGES OF THE NEW YORK BOTANICAL GARDEN.

New York. The guests included the scientific directors of the garden and a number of other distinguished representatives of botany and other sciences. On this occasion a loving cup was presented to Dr. Britton, bearing an inscription that the cup was presented "in recognition of his distinct services to the Garden, public education, and science." The then president of the board, Dr. W. Gilman Thompson, announced that the dinner was not given in celebration of any event or anniversary, but solely as an expression of the good-will, esteem and confidence of the board of managers.

The appointment of Dr. E. D. Merrill as director-in-chief, in succession to Dr. Britton, will take effect as of January 1, 1930. In the interim, Dr. Marshall A. Howe, a member of the original staff of the garden, and for some years assistant director-in-chief, will be acting director.

Professor Elmer D. Merrill, who will succeed Dr. N. L. Britton as director-in-chief of the New York Botanical Garden on January 1, 1930, is a native of East Auburn, Maine. After graduating from the University of Maine in 1898 (with honorary degrees of M.S., 1904, and Sc.D., 1926), Dr. Merrill held various appointments in George Washington University, the University of Maine, the United States Department of Agriculture and the Insular Bureau of Agriculture, the Bureau of Forestry, Bureau of Government Laboratories and Bureau of Science, Manila, P. I. From 1919 to 1923, Dr. Merrill was director of the Bureau of Science and associate professor of botany and head of the department, Philippines, 1912 to 1917, with the title of professor, 1917 to 1919 and professorial lecturer, 1919 to 1923. Since 1924 he has been professor of agriculture and director of the Experiment Station, University of California, and director of the California Botanic Garden since 1927. From 1906 to 1923, Dr. Merrill was editor of the *Philippine Journal of Science* and editor of *Hilgardia* from 1925.

Professor Merrill is a member of the National Academy of Science, the Société botanique de France, the Botanische Gesellschaft and the Royal Asiatic Society, as well as numerous American scientific societies. He is a recognized authority in the systematic botany of China, Philippines and adjacent islands, and comes to the New York Botanical Garden richly acquainted with the important scientific administrative duties of that position.

C. S. G.

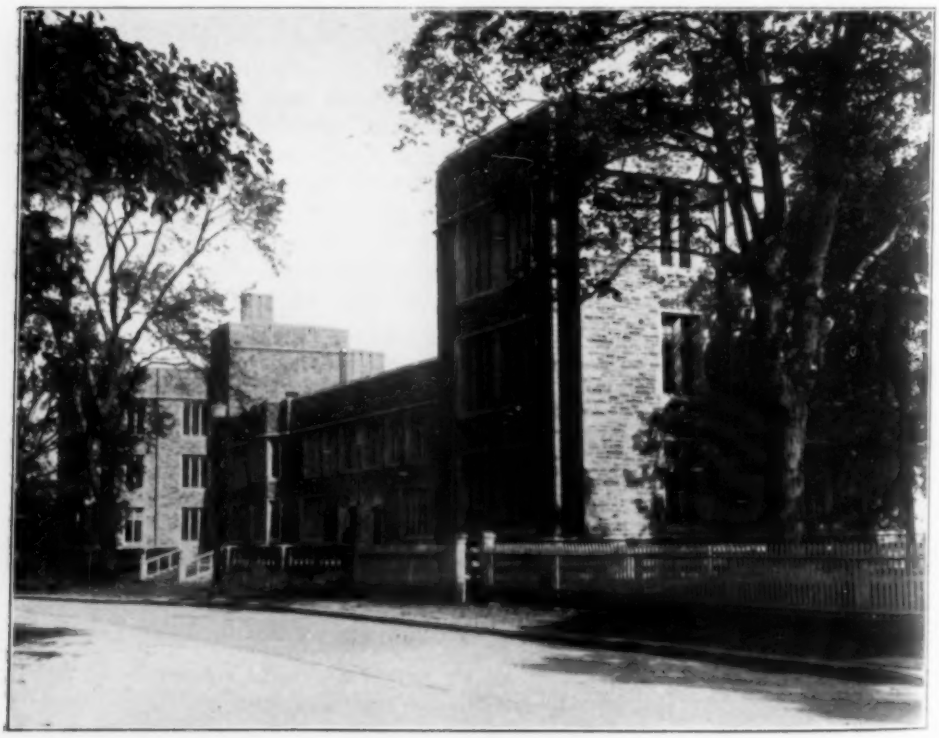
DEDICATION OF THE CHEMISTRY BUILDING AT PRINCETON UNIVERSITY

DISTINGUISHED scientists met at Princeton, New Jersey, September 26, 27 and 28, 1929, to attend the dedication of the new laboratory, and to be present at the international conference on catalysis and the mechanism of chemical reactions.

At 12:30 P. M., on September 26, the academic procession marched to the auditorium of the laboratory, and, following the singing of "America," Charles Z. Klauder, the architect, presented the symbolic key of the building to President Hibben. Mr. Klauder pointed out that one prominent feature of the laboratory is the centrally located stockroom.

President Hibben accepted the key for the university, saying that the laboratory would not be justified if the university had not had at its disposal the recently completed fund of 3,000,000 for research in pure science, and if it did not have men capable of conducting excellent research.

Professor Hugh S. Taylor, chairman of the department of chemistry, then delivered the chief address. He said that the successive laboratories at Princeton had covered the whole epoch of modern chemistry, and closed his address as follows: "We are indeed fortunate here that ways have been devised to ensure close cooperation between the sciences and, by reason of that cooperative effort, we are drawing ever-increasing numbers of students to our graduate schools from all parts of the world. We commend especially to the parents and guardians of our Princeton undergraduates a serious consideration of the rich opportunities for scientific training which Princeton now offers in contrast with earlier decades, and we



THE NEW CHEMISTRY BUILDING AT PRINCETON

PROFESSOR MAX BODENSTEIN
DIRECTOR OF THE INSTITUTE OF PHYSICAL CHEMISTRY AT THE UNIVERSITY OF BERLIN, WHO PRESENTED HIS WORK ON CATALYTIC OXIDATION OF AMMONIA.

PROFESSOR KARL F. BONHOEFFER
OF THE KAISER WILHELM INSTITUTE, DISCOVERER OF PARAHYDROGEN, WHO PRESENTED A REPORT OF HIS WORK.

bespeak their counsel and encouragement to their sons seriously to consider the opportunities to which they are heir. In return for their labors we offer them a life in science rich in its satisfaction, full, scholarly and enduring. *'Non est mortuus qui scientiam vivificavit.'*"

At the close of Professor Taylor's address the honorary degree of D.Sc.

PROFESSOR M. POLANYI
OF THE KAISER WILHELM INSTITUTE, WHO PRESENTED A PAPER ON ATOMIC REACTIONS IN HIGHLY DILUTE FLAMES.

(Doctor of Science) was conferred by the university on the following visiting chemists: Professor Max Bodenstein, director of the Physikalisch-Chemisches Institut, Berlin, Germany; Professor F. G. Donnan, F.R.S., University of London; Sir James C. Irvine, principal of St. Andrews, Fife, Scotland; Dr. Irving Langmuir, assistant director of the research laboratories, General Electric Company, Schenectady, N. Y., and Professor Jean B. Perrin, director of the Laboratoire de Chimie-Physique, Paris.

The exercises were concluded by Dean Robert R. Wicks, of the University Chapel, who pronounced a prayer and benediction, and by the singing of "Old Nassau."

The guests were entertained at luncheon at the Princeton Inn, and in the afternoon the ladies of the chemistry department held a reception in the library of the laboratory.

On the evening of the same day Professor F. G. Donnan, of the University of London, gave a public lecture on "The Application of Physical Chemistry to Chemical Industry with Special Reference to Catalysis."

The Chemical Laboratory and equipment cost over $1,500,000. In addition to offices and laboratories of faculty members, it has nine large laboratories and thirty smaller ones, the former being for undergraduates and the latter for men engaged in research.

The small laboratories have very little permanent apparatus in them, and are so arranged that any type of equipment may be employed from time to time. Every room has outlets for all types of electric current; and steam, gas, hot and cold water, and compressed air are piped to every room.

The main lecture room is completely equipped, and can be darkened easily and quickly by touching a button. The library is comfortably furnished; it contains two fireplaces which are attractively panelled, and above them are inscribed the following mottoes:

FELIX QVI POTVIT RERVM
COGNOSCERE CAVSAS

"Happy is he who hath learned the whence and wherefore of things" (Vergil, Georgics, II, 490); and

NON EST MORTVVS QVI
SCIENTIAM VIVIFICAVIT

"He is not dead who hath given new life to knowledge." (Quoted by Richard de Bury, Philobiblon, Chap. 19, from Amagest of Ptolemy the Mathematician, who lived about 139 A. D. The original work, in Greek, has been lost.)

At the conference on catalysis and the mechanism of chemical reactions the following papers were read and discussed:

Chemical and Electrical Properties of Adsorbed Films on Tungsten: DR. IRVING LANGMUIR, of the General Electric Company.

The Mechanism of the Catalytic Oxidation of Ammonia: PROFESSOR MAX BODENSTEIN, of the University of Berlin.

Fluorescence and the Problem of Negative Catalysis: DR. FRANCIS PERRIN, of Paris.

Trace Catalysis and Chain Reactions: C. N. HINSHELWOOD, of Trinity College, Oxford, England.

Atomic Reactions and Luminescence in Highly Dilute Flames: PROFESSOR M. POLANYI, of the Kaiser Wilhelm Institut, Berlin.

Parahydrogen, Atomic Hydrogen and the Mechanism of Flame Reactions: DRS. K. F. BONHOEFFER and P. HARTECK, of the Kaiser Wilhelm Institut, Berlin.

Finally, Professor Hugh S. Taylor summarized the following communications:

"The Historical Development and Theory of Ammonia Synthesis," by Drs. A. Mittasch and Frankenburger, of the I. G. Laboratories, Oppau, Germany, and "Kinetics and Adsorption at Contact Surfaces," by Drs. H. Mark, Dohse and Kälberer, of the I. G. Laboratories, Ludwigshafen, Germany.

WILLIAM FOSTER